Appendix II

STATISTICAL ANALYSES OF FLOWS IN THE NORTH PLATTE RIVER AND ITS TRIBUTARIES BETWEEN THE STATE LINE AND LEWELLEN

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INTRODUCTION

Objective of the Study

The objective of this study is to determine if stream flows in the Stateline to Lewellen reach of the North Platte River and its tributaries have declined and if so to try to ascertain the possible causes of any declines. The major source of water for the North Platte River between the Wyoming-Nebraska state line and Lewellen is the release of storage water for irrigation from the U. S. Bureau of Reclamation reservoirs in Wyoming. The majority of this water is diverted in Wyoming by the Interstate and Fort Laramie canals and a number of smaller Wyoming canals or by the Tri-State and Mitchell-Gering Canals at the state line. The Interstate and Fort Laramie Canals serve land both in Wyoming and Nebraska; Tri-State and Mitchell-Gering Canals serve land in Nebraska. All these diversions produce a large amount of return flow, which provides water for the numerous tributaries in this reach (Figure 1).

In 1911 before these canals were built, there were no perceptible tributary flows west of Bridgeport, Nebraska (Willis, 1930), but starting in 1911, with the beginning of diversions by the large canals, the flows in these tributaries increased. By the 1930s, the return flow in tributaries from irrigation between the state line and Minatare, Nebraska was over 326,000 acre-feet (Wenzel, et al. 1946). These return flows in turn provide the major source of natural flow in the main stem and on the tributaries of the river between the state line and Lewellen. Figure 2 shows the historic contribution to flow from the major North Platte River tributaries.

In recent years concerns have been raised that these return flows have been decreasing. Currently identified potential factors that could be causing any observed stream flow declines include a decline in the release of reservoir storage water, a decline in local precipitation, an increase in the number of acres served by surface water, increased use of ground water by wells and the impact of soil and water conservation measures that cause an increase in consumptive use.

Methods

A step-wise linear regression was used to try to determine what factors may be causing any observed changes. The factors examined included reservoir releases, local precipitation, canal diversions and ground water pumping. Gaging records for streams and canal diversions between the Wyoming-Nebraska State Line and Lewellen were also analyzed using graphical, simple linear trend analysis and the Mann-Whitney U test to determine if there were any increasing or decreasing trends.

Acknowledgements

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DATA INVENTORY

Data used in the study include gaging records from the U.S. Geological Survey (USGS) web site; the Nebraska Department of Natural Resources (NDNR) Data Bank, including the registered well database; the former Nebraska Department of Water Resources (NDWR) Biennial/Hydrographic Reports; and the U.S. Bureau of Reclamation (USBR) North Platte River Compiled Water Records.

Stream Flow and Canal Diversion

Figure 3 depicts the main stem and tributary gaging stations and canal diversions from the North Platte River between the state line and Lewellen that were used in the study. Diversions for the Interstate and Fort Laramie Canals in Wyoming and reservoir release data from the Guernsey Reservoir were also analyzed. Table 1 is a list of the gaging stations analyzed and their period of record.

Precipitation

Monthly precipitation at the Mitchell 5E Station (#25-5590) was retrieved from NDNR Data Bank. The Mitchell 5E station was selected because it had continuous data since 1930. For years 1999 and 2002, the data at Scottsbluff AP (#25-7665) were used because the Mitchell station was discontinued in 1998. Precipitation data at the Crescent Lake Station (#25-2000) for the period of 1949-2002 were also included in the study.

Irrigated Acreage

A number of data sources were checked to try to determine the number of irrigated acres through the entire study period. Although various data sets exist, the data conflict and no one source provided a reliable measure of the number of acres irrigated by surface water and or groundwater during the entire study period. Data developed for Nebraska's lawsuit against Wyoming (Figure 4) provide the best assessment of surface water irrigated acres in the North Platte Basin (Martin, 2000), but the data are only available up to 1994. However, since 1993 there has been a moratorium on new surface water permits in the North Platte River Basin. Therefore it is unlikely that surface water irrigated acres have substantially increased since the termination of Martin's study.

Ground Water Pumping

Historical measurements of ground water pumping do not exist. Therefore, the study relied on records of ground water well registrations to provide an indication of the amount of ground water pumping that occurred through time. Well registrations are a poor indicator of ground water pumping because not all registered wells pump every year and even when the wells are pumped, the amount pumped may vary considerably. Variations in pumping from year to year are particularly pronounced on wells that are not the sole source of irrigation but are used to supplement surface water supplies. Figure 5 shows the cumulative number of registered irrigation wells by year.

Conservation Practices

Other than center pivot inventories and sporadic irrigation district records showing when and where canals were lined, records on the implementation of conservation practices in the basin are practically nonexistent.

Total Contribution from Tributaries

Figure 2 shows the historic contribution to flow in the NPR from major tributaries between the state line and Lewellen. Diversions from those tributaries were included as part of the total water supply.

Data on the historic tributary stream flows into the North Platte River reach were inventoried. A list of those gauging stations is shown in Table 2. Because the reporting for some of the tributaries was discontinued in 1988, the annual total tributaries into the North Platte River reach for 1988-2002 was adjusted by the average annual amount of total tributaries from those discontinued gauges during the period of 1931-1987. Historical diversions from return flows were obtained from canal diversion records (Table 3).

To display a consistently gauged historical contribution from tributaries (1931-2002), the total contribution of nine tributaries for which there is continuous data is presented in Figure 6.

REGRESSION ANALYSES

Regression analysis can be used to determine the correlation relationship between a dependant variable (response) and independent variables (predictors). The coefficient of determination (R^2) of a resulting regression equation indicates the amount of variation in response accounted for by selected predictor(s). A step-wise regression technique was used to identify causal factors for some selected response variables.

Step-wise regression is a procedure that generates a model by including variables in or excluding variables from the model based on the specified Alpha-to-Enter and Alpha-to-Remove values. For this analysis, Alpha-to-Enter and Alpha-to-Remove of 0.05 were selected. Thus, at each step of the procedure, a predictor is added to the model, because it has the smallest p-value among those predictors with p-values less than 0.05. Similarly, at each sequential step of the procedure, a predictor is only removed from the model if it has the largest p-value among those predictors with p-values greater than 0.05.

For regression analyses, the following annual response data series of 1961-2002 were selected:

- Flow of North Platte River at Lewellen, *Lewellen*
- Total tributaries between Wyoming-Nebraska state line and Bridgeport, *TotTrib*
- Total tributaries from the north side of the North Platte River reach between state line and Bridgeport, *NorthTrib*.
- Tributaries of Sheep Creek, Akers Draw, Dry Spotted Tail Creek, Tub Springs, and Winters Creek, *TotalFive*
- Total tributary of Sheep Creek, *Sheep*
- Total Tri-State Canal irrigation diversion from tributaries, *TStrib*
- Total irrigation diversion from tributaries, *DivTrib*

The potential predicting data series variables for the above response data series used in this analysis are:

- Annual precipitation at station Mitchell 5 E, *Precip*
- Guernsey Reservoir outflow, *Guernsey*
- Interstate Canal diversions in present year, 1-year ago, 2-year ago, 3-year ago, and 4-year ago respectively, *IntState, IS1, IS2, IS3*, and *IS4*
- Tri-State Canal diversions from the North Platte River in present year, 1-year ago, and 2-year ago respectively, *TSNP, TSNP1*, and *TSNP2*
- Fort Laramie Canal diversion, *Laramie*
- Cumulative number of irrigation wells within the surface water drainage of the reach of the North Platte River below the Nebraska State Line to Bridgeport, Nebraska, excluding those above the Ft. Laramie Canal on Horse Creek, *IrrWells*

- Cumulative number of irrigation wells below the Nebraska State Line, along the North Platte River Basin above Bridgeport, on the north side of the river only, *NorthWell*
- Cumulative number of irrigation wells within the drainage areas of Sheep Creek, Akers Draw, Dry Spotted Tail Creek, Tub Springs, and Winters Creek, *FiveWell*
- Cumulative number of irrigation wells in the drainage area of Sheep Creek, *SheepWell*

The impact of wells on the tributaries on the south side of the river, Horse Creek and Gering Creek, was not tested because there is little or no aquifer and few wells that affect south side tributary flows.

Results

Regression analyses results for each response variable, potential causal variables used for regression analysis, and the resulting regression equation (model) for each data series are summarized in Table 4. The coefficient of determination (R^2) for each equation presents the percentage variation in the response variable that can be explained by those predictors in the equation.

Discussion

The hydrographs (Figure 7) and statistical analyses indicate the importance of the outflow from Guernsey Reservoir on the North Platte River flows at Lewellen with Guernsey outflow accounting for 91% of the variance in flow at Lewellen. Also important are the return flows from irrigation diversions of Interstate Canal and Tri-State Canal. Interstate Canal diversions account for 88% of the variance in the flow of Sheep Creek. Interstate Canal diversions, Tri-State Canal diversions and precipitation account for 64%, 9%, and 6.3%, respectively of the variance in the five tributaries of Sheep Creek, Akers Draw, Dry Spotted Tail Creek, Tub Springs, and Winters Creek. Interstate Canal diversions also account for almost 69% of the variance in the total Tri-State Canal irrigation diversion from tributaries. These results indicate that the Interstate Canal diversion is a major source of flow in the tributaries. For the variations in the total flow of north side tributaries in the North Platte River reach, Interstate Canal diversions are also a major source of flow to other tributaries on the north side of the North Platte River accounting for almost 72% of the variance. Local precipitation and Tri-state Canal diversions from the North Platte River account for 7.6% and 2.3%, respectively of the variance in flow of these tributaries.

Although the numbers of registered irrigation wells were tested in the regression equations, they were never considered to be a significant variable. This result is not surprising because the relative importance of canal diversions is so great in comparison to the impact from groundwater pumping, the statistical test used may not have been sensitive enough to pick up the impact of wells.

TREND ANALYSES

A study period of 1961-2002 was selected to account for the full effect of major North Platte River projects. 1961 is the year when Glendo Reservoir filled providing the capacity to store up to 100,000 acre feet of irrigation water, which increased the amount of water available for diversions and return flows. Simple linear trend analyses were performed using the MINITAB Statistical Software (MINITAB Inc., 2000). By selecting a confidence level of 95-percent, a trend was considered to be statistically significant if the probability (p) value (probability that a true null hypothesis of no trend is erroneously rejected) was less than or equal to 0.05. Those fitted trend lines with a p-value greater than 0.05, are statistically considered to be insignificant at the selected confidence level of 95-percent.

Results

Hydrographs, along with the 1961-2002 trend lines, 10-year period moving average trends for data 1931 onward are also depicted in Figures 8-37. A moving average trend displays the average trend of a data series by smoothing out individual high and low values. Trend analyses results are presented in Table 5. A positive sign and a negative sign represent an increasing and decreasing trend, respectively. There are no significant trends in precipitation, the outflow from Guernsey Reservoir or for total Tri-State Canal diversions for the study period of 1961-2002. There were significant decreasing trends at the 95-percent confidence level for Interstate Canal annual diversions, Tri-State Canal annual diversion from tributaries, total October and November tributary flows between the state line and Bridgeport, total tributary flows on the north side of the river, flows of Sheep Creek and Blue Creek and the number of surface water irrigated acres up to 1994. Statistically significant increasing trends were observed for the number of registered irrigation wells, Tri-State Canal annual diversion from North Platte River, and for flows in Dry Spotted Tail Creek, and Gering Creek.

Discussion

Trend analyses can be somewhat misleading because the trend can change depending on what years were chosen to be analyzed. If the analysis starts in a wet period and ends in a dry period, a downward trend will be detected even though starting the trend during a different part of the cycle would have shown an upward trend. However, trend analyses of Guernsey Reservoir releases and area precipitation, the two major sources of water supply for the area, showed no significant decreases for the study period. On the other hand there were significant declines in tributary flows in the area.

The decrease in diversion to Interstate Canal may reflect the decrease in available natural flow for a junior water right. The decrease in diversion by Tri-State Canal from tributaries most likely reflects decreases in available water supply.

The decreasing trend in surface water irrigated acreage indicates that increases in consumptive use from surface water irrigation are not the likely cause for decreased tributary flows. On the other hand, the number of registered irrigation wells showed a significant increase during the study period. Although the number of registered wells does not provide an accurate estimate of the volume of groundwater pumped in any given year, the significant increase in the number of irrigation wells indicates that groundwater use has increased during the study period.

The pattern of monthly trends for the tributaries is of particular interest. Tributary flows (including surface water diversions from the tributaries) show no significant change from 1961-2002 for the months of July, August, and September. In fact they show a slightly increasing trend in July and August. Flows start to decrease in September with a statistically significant decrease in October and November. A possible explanation for those patterns could be related to the timing of the impacts of ground water pumping on stream flows. In July and August, some of ground water used for irrigation runs off the field as surface water flow and tends to augment stream flow, offsetting declines in stream flow due to ground water pumping during the months of July and August and possibly some of September. However, much of the decrease in water table elevations as a result of pumping may not impact stream flows for several months. This lag effect of the impact of stream flow is likely the cause of decreases in tributary flows in September, October, and November.

The Mann – Whitney U Test

A second statistical test was utilized in order to better understand the potential impact of ground water wells on tributary flows. The Mann-Whitney U test is a nonparametric statistical test similar to the Student T test that determines if there is a significant difference between the statistical parameters of two different populations. Two time periods, one during a period at the beginning of well development, and one toward the later period of well development were compared using the Mann-Whitney U test. Figure 38 is a plot showing the relationship among the total flow of north side tributaries, Interstate Canal diversions, local precipitation, and the cumulative number of irrigation wells. To further examine the factors affecting tributary flow, the Mann-Whitney U Test was used to test if there was a significant difference between the medians of north tributary flows, Interstate Canal diversions, local precipitation, and the cumulative number of wells for the two periods.

At a confidence level of 95-percent, the Mann-Whitney U Test results indicate that the median flow of north tributaries during 1993-2001 was significant lower than median flow of north tributaries during 1971-1982. The median of the cumulative number of wells was significant higher in the later period. However there was not a significant difference between the medians of Interstate Canal diversions and local precipitation during the two time periods. These results indicate that the north side tributaries decrease in median annual flow was at least partially caused by the increase in the number of wells.

DISCUSSION

The hydrographs and statistical analyses indicate the importance of the outflow from Guernsey Reservoir on the North Platte River flows at Lewellen, with Guernsey outflow accounting for 91% of the variance in flow at Lewellen. Also important are the return flows from irrigation diversions of Interstate Canal and Tri-State Canal. Interstate Canal diversions account for 64% of the variance in the five tributaries of Sheep Creek, Akers Draw, Dry Spotted Tail Creek, Tub Springs, and Winters Creek on the north side, with Tri-State Canal diversions and precipitation accounting 9% and 6.3% of the rest, respectively. Although precipitation is a significant contributor to the water supply of the North Platte River above Lewellen, the major source of water is clearly from the North Platte River in Wyoming.

The outflow from Guernsey Reservoir and local precipitation, the major source of water for all the North Platte tributaries above Bridgeport, showed no significant change during the study period. Nevertheless, Interstate Canal diversions, the north side tributaries, the October and November tributaries flows, and the flows on Sheep Creek and Blue Creek all showed statistically significant declines. The flows on Gering Creek, Bayard Creek, and Dry Spotted Tail Creek, on the other hand, showed a significant increasing trend. The increasing trend in Dry Spotted Tail Creek is most likely due to the fact that in recent times Western Sugar stopped diverting from Dry Spotted Tail Creek and the Dutch Flats tributary, which empties into Dry Spotted Tail Creek, has been better maintained.

There are several potential causes for the decrease in tributary flows: the decline in surface water diversions, the increase in groundwater irrigated acres as reflected by the increased number of groundwater wells, and increased consumptive use due to increased efficiencies of water use.

The results of the Mann-Whitney U test indicate that during two periods during which there was no significant difference in Interstate Canal diversions and in precipitation. However, significant declines in tributary flows during a period of significant increases in the number of wells in the area clearly indicates groundwater pumping as a probable cause of stream flow declines. Though not analyzed because of lack of data, other factors such as increased water use efficiencies due to canal lining and increased use of center pivots and other conservation activities may also be contributing to stream flow declines. Thus, although important, ground water use is probably not the only factor causing recent declines in streamflow in the North Platte River Basin.

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Table 1. North Platte River Gaging Stations

Station_ID	Station Name	First Year	Last Year
200500	AKERS DRAW NEAR MORRILL	1959	1994
6683000	BAYARD CREEK NEAR BAYARD	1931	2002
7000	BEERLINE CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1941	2002
9000	BELMONT CANAL FROM NORTH PLATTE RIVER (15-FOOT PARSHALL RIVER)	1933	2002
6687000	BLUE CREEK NEAR LEWELLEN, NE	1931	2002
19000	BROWNS CREEK CANAL FROM NORTH PLATTE RIVER (8 FOOT PARSHALL FLUME)	1933	2002
21000	CASTLE ROCK-STEAMBOAT CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
204000	CEDAR CREEK NEAR BROADWATER	1931	1989
22000	CENTRAL CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
24000	CHIMNEY ROCK CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
206000	CLEVELAND DRAIN NEAR BAYARD	1931	1990
207000	COLD WATER CREEK NEAR LISCO	1953	1989
6679000	DRY SPOTTED TAIL CREEK AT MITCHELL	1931	2002
209000	DUGOUT CREEK, UPPER, NEAR BRIDGEPORT	1931	1990
39000	EMPIRE CANAL FROM NORTH PLATTE RIVER VIA BELMONT CANAL (4-FOOT PARSHALL FLUME)	1957	2002
40000	ENTERPRISE CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
52200	FT. LARAMIE CANAL AT MILEPOST 85.3, NE (STATE LINE)	1981	2002
6681500	GERING CREEK NEAR GERING, NE	1931	2001
6677500	HORSE CREEK NEAR LYMAN, NE	1931	2002
217000	INDIAN CREEK NEAR NORTHPORT	1931	1990
71000	INTERSTATE CANAL	1933	2002
82000	LISCO CANAL FROM NORTH PLATTE RIVER (WEIR)	1933	2002
224000	MELBETA DRAIN NEAR MELBETA	1931	1990
98000	MIDLAND-OVERLAND CANAL FROM NORTH PLATTE RIVER 4 FOOT (PARSHALL FLUME)	1933	2002
99000	MINATARE CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
106000	NINE MILE CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
6682500	NINE MILE CREEK NEAR MCGREW	1931	2002
6684500	NORTH PLATTE RIVER AT BRIDGEPORT, NE	1923	2002
6687500	NORTH PLATTE RIVER AT LEWELLEN, NE	1941	2002
6686000	NORTH PLATTE RIVER AT LISCO, NEBR.	1932	2002

Table 1. North Platte River Gaging Stations -- Continued

Station_ID	Station Name	First Year	Last Year
6679500	NORTH PLATTE RIVER AT MITCHELL, NEBR.	1923	2002
6674500	NORTH PLATTE RIVER AT WYOMING-NEBRASKA STATE LINE	1930	2000
6682000	NORTH PLATTE RIVER NEAR MINATARE, NE	1924	2002
6685000	PUMPKIN CREEK NEAR BRIDEGPORT, NE	1931	2002
6684000	RED WILLOW CREEK NEAR BAYARD	1931	2002
6678000	SHEEP CREEK NEAR MORRILL	1931	2002
133000	SHORT LINE CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
230000	SILVERNAIL DRAIN NEAR BRIDGEPORT	1956	1989
145100	TRI-STATE CANAL FROM NORTH PLATTE RIVER	1933	2002
6680000	TUB SPRINGS NEAR SCOTTSBLUFF	1931	2002
147500	WET SPOTTEDTAIL CREEK NEAR MITCHELL	1931	1987
6681000	WINTER CREEK NEAR SCOTTS BLUFF	1931	2002
148000	WINTERS CREEK CANAL FROM NORTH PLATTE RIVER (8-FOOT PARSHALL FLUME)	1933	2002
GUER	GUERNSEY RESERVOIR OUTFLOW	1946	2002

Table 2

A Station List of Historic Drains into the North Platte River

(Between State Line and Bridgeport)

Station_ID	Gauging Station Name	Data Period
	Bald Drain	1931-1987
6683000	**Bayard Sugar factory Drain**	**1931-2002**
	Camp Clark Seep	1931-1936
	Castle Rock Seep	1938-1941
	Cleveland Drain	1931-1990
	DeGraw Drain	1931-1987
	Dugout Creek, Upper	1931-1990
	Fairfield Seep	1931-1987
	Fanning Seep	1931-1987
6681500	**Gering Drain**	**1931-2002**
6677500	**Horse Creek**	**1931-2002**
	Indian Creek	1931-1990
	Lane Drain	1931-1987
	Melbeta Drain	1931-1990
	Mitchell Spillway	1931-1942
6682500	**Nine Mile Drain**	**1931-2002**
6684000	**Red Willow Creek**	**1931-2002**
	Scottsbluff Drain No. 1	1931-1987
	Scottsbluff Drain No. 2	1932-1987
6678000	**Sheep Creek**	**1931-2002**
6679000	**Spottedtail, Dry**	**1931-2002**
	Spottedtail, Wet	1931-1987
	Toohey Drain	1931-1935
	Toohey Spill	1931-1942
6680000	**Tub Springs**	**1931-2002**
6681000	**Winters Creek**	**1931-2002**

Note: Bold stations have continuous data records from 1931 to present.

Table 3

A Station List of Historic Canal Diversions from Drains

(Between State Line and Bridgeport)

Station ID	Gauging Station Name	Data Period(s)
2000	Alliance Canal from Bayard Drain	1931-2002
3000	Alliance Canal from Red Willow Creek	1931-2002
42000	Enterprise Canal from Morrill Drain	1931-1996
43000	Enterprise Canal from Tub Springs	1931-1996
44000	Enterprise Canal from Winters Creek	1961-1996
41000	Enterprise Canal from Dry Spottedtail Creek	1960-1996
42500	Enterprise Canal from Stewart Drain	1931-35;1948
42700	Enterprise Canal from Wet Spottedtail Creek	1931-60;1995-96
106100	Nine Mile Canal from Nine Mile Creek	1931-46; 63-65; 70-77; 88-2002
144400	Tri-State Canal from Alliance Creek	1931-44; 1996-97
144500	Tri-State Canal from Akers Draw	1931-2002
144700	Tri-State Canal from Sheep Creek	1931-2002
144600	Tri-State Canal from Dry Spottedtail Creek	1931-2002
144900	Tri-State Canal from Wet Spottedtail Creek	1931-2002
144800	Tri-State Canal from Tub Springs	1931-2002
149000	Winters Creek Canal from Winters Creek	1931-2002

Table 4. Step-wise Regression Analyses of Annual Data Series

(In the parentheses, each individual variable's contribution to the variation of the response variable is listed in *italics*.)

Response	Potential Predictors	Regression Equation	Coefficient of Determination, R^2 (%)
North Platte River Flow at Lewellen, *Lewellen*	Precip, IrrWells, Guernsey	Lewellen = 1.271Guernsey + 22.6Precip – 748.1	93.67 (*Guernsey=91, Precip=2.7*)
Total Drains Between Stateline & Bridgeport, *TotTrib*	Precip, IrrWells, IntState, IS1-4, TSNP, TSNP1-2, Laramie	TotTrib = 0.94IntState + 0.38IS2 + 0.86TSNP1 + 7.1Precip – 325.32	66.87 (*IntState=54.7, TSNP=5, Precip=7.1*)
Drains from the Northside of the N. Platte River Reach, *NorthTrib*	Precip, NorthWell, IntState, IS1-4, TSNP, TSNP1-2,	NorthTrib = 0.39IntState +0.282IS2 + 0.316IS1+4.8Precip + 0.185IS3 + 0.35TSNP – 249.88	81.71 (*IntState=71.8, Precip=7.6, TSNP=2.3*)
Total Drain of Sheep, Akers, DrySpot, Tub Springs, and Winters Creek, *TotalFive*	Precip, FiveWell, IntState, IS1-4, TSNP, TSNP1-2	TotalFive = 0.210IntState + 0.081IS2 + 0.247TSNP1 + 1.27Precip + 0.055IS3 – 42.46	79.29 (*IntState=64, TSNP=9, Precip=6.3*)
Annual Total Drain of Sheep Creek, *Sheep*	Precip, SheepWell, IntState, IS1-4, TSNP, TSNP1-2	Sheep = 0.055IntState + 0.055IS1 + 0.023IS3 + 0.039IS2 – 0.051TSNP2 + 0.29Precip + 0.014IS4 – 16.85	92.77 (*IntState=88.1, TSNP=3.4, Precip=1.3*)
Tri-State Canal Diversion from Drains, *TStrib*	Precip, IntState, IS1-4	TStrib = 0.074IntState + 0.037IS2 + 0.032IS1 – 25.446	68.64
Total Irrigation Diversion from Drains, *DivTrib*	Precip, IntState, IS1-4, TSNP, TSNP1-2	DivTrib = 0.079IntState + 36.42	33.69

Table 5. Results of Trend Analyses of Data Series

[Shading indicates statistically significant at the 95-percent confidence level (probability value less than 0.05). Insignificant trend is likely to be a result of chance.]

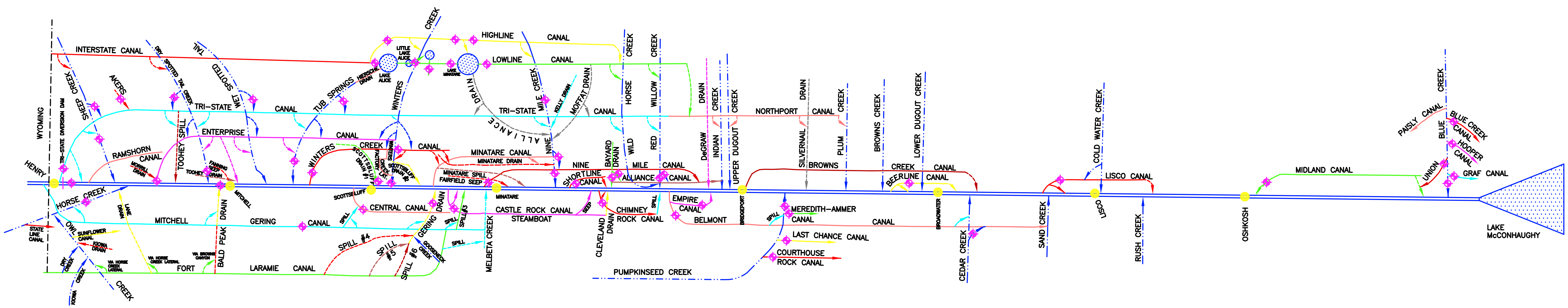
Annual Data Series Name	Probability (p-value)	Slope [KAF/Year]	Increasing (+) or Decreasing (-) Trend
Annual Precipitation at Mitchell 5E	0.495	-0.031*	
Guernsey Reservoir Outflow	0.952	-0.284	
Interstate Canal Diversion	0.011	-2.125	-
Ft. Laramie Canal Diversion	0.599	-0.134	
Tri-State Canal from N. Platte River	0.004	1.090	+
Tri-State Canal from Tributaries	0.003	-0.302	-
Total Tri-State Canal Diversion	0.072	0.788	
Total July Tributary Flows	0.945	0.012	
Total August Tributary Flows	0.740	0.058	
Total September Tributary Flows	0.210	-0.285	
Total October Tributary Flows	0.000	-0.293	-
Total November Tributary Flows	0.001	-0.183	-
Total Summer Tributary Flows (July-October)	0.348	-0.557	
Total Tributaries from South Side of the River	0.710	0.168	
Total Tributaries from North Side of the River	0.024	-1.679	-
Total Tributaries between Stateline & Bridgeport	0.181	-1.511	
Total Diversion from Tributaries	0.566	-0.067	
Horse Creek near Lyman	0.123	0.510	
Sheep Creek	0.000	-0.371	-
Dry Spotted Tail Creek	0.041	0.128	+

Table 5. Results of Trend Analyses of Data Series---Continued

Annual Data Series Name	Probability (p-value)	Slope [KAF/Year]	Increasing (+) or Decreasing (-) Trend
Tub Springs	0.909	-0.007	
Winters Creek	0.267	-0.065	
Gering Creek near Gering	0.017	0.299	+
Nine Mile Creek	0.291	-0.140	
Bayard Creek	0.210	0.052	
Red Willow Creek	0.556	-0.101	
Blue Creek	0.037	-0.078	-
North Platte River at Lewellen	0.787	-1.689	
Surface Water Irrigated Acres	0.003	-312.319**	-
Number of Registered Wells	0.000	20.1504***	+

*The slope for precipitation is in inches per year,
** The slope for the surface water irrigated acres is in acres per year, and the data period is 1961-1994, and
***The slope for the number of wells is in number per year.

Canal Network from the Nebraska-Wyoming Stateline to Lake McConaughy along the North Platte River



LEGEND

- GAGING STATION
- CITIES
- RESERVOIR
- CANAL
- CREEK
- DRAIN

NOTE:
* ALL CANALS HAVE A GAGING STATION
* RAMSHORN CANAL IS CANCELLED

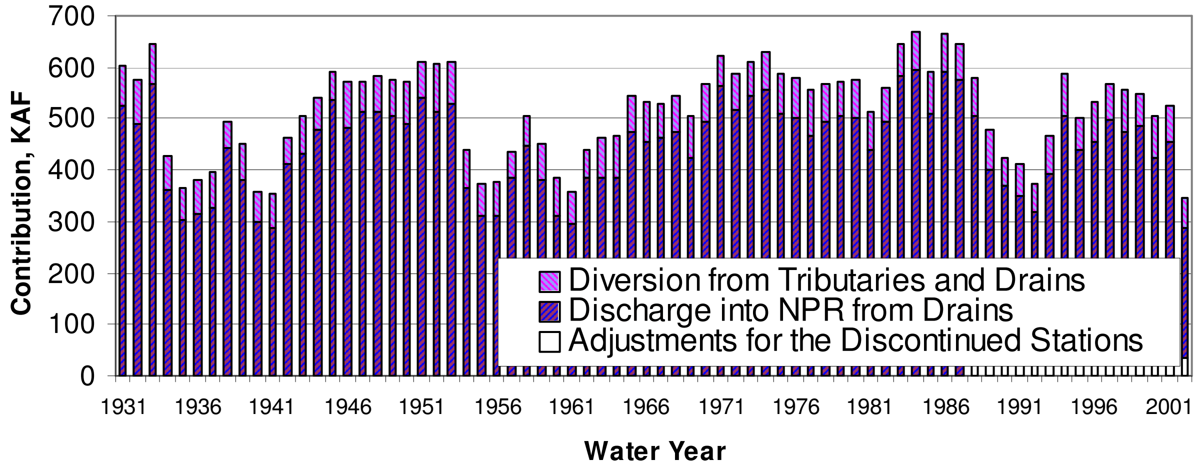
NOT TO SCALE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.	TITLE: CANAL SCHEMATIC	SCALE:	SHEET:	DWN BY:	APP'D BY:	DATE:	PROJECT NUMBER:	REV:
				MGL		AUG 94	10387.01	

Figure 1

Figure 2 Historic Contribution from Tributaries and Drains

(Between State Line and Bridgeport)



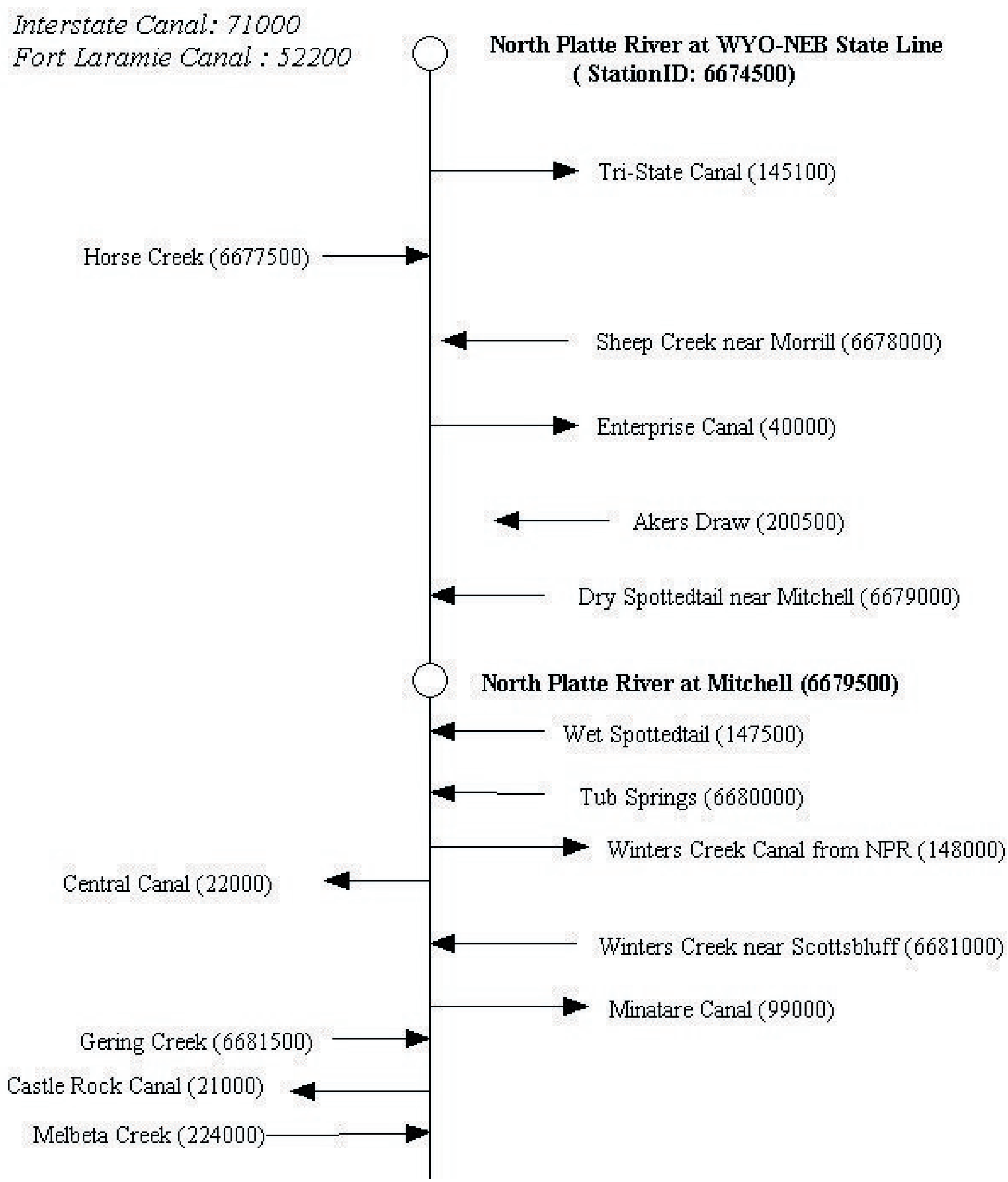
Tributaries and Drains are as of 1986:

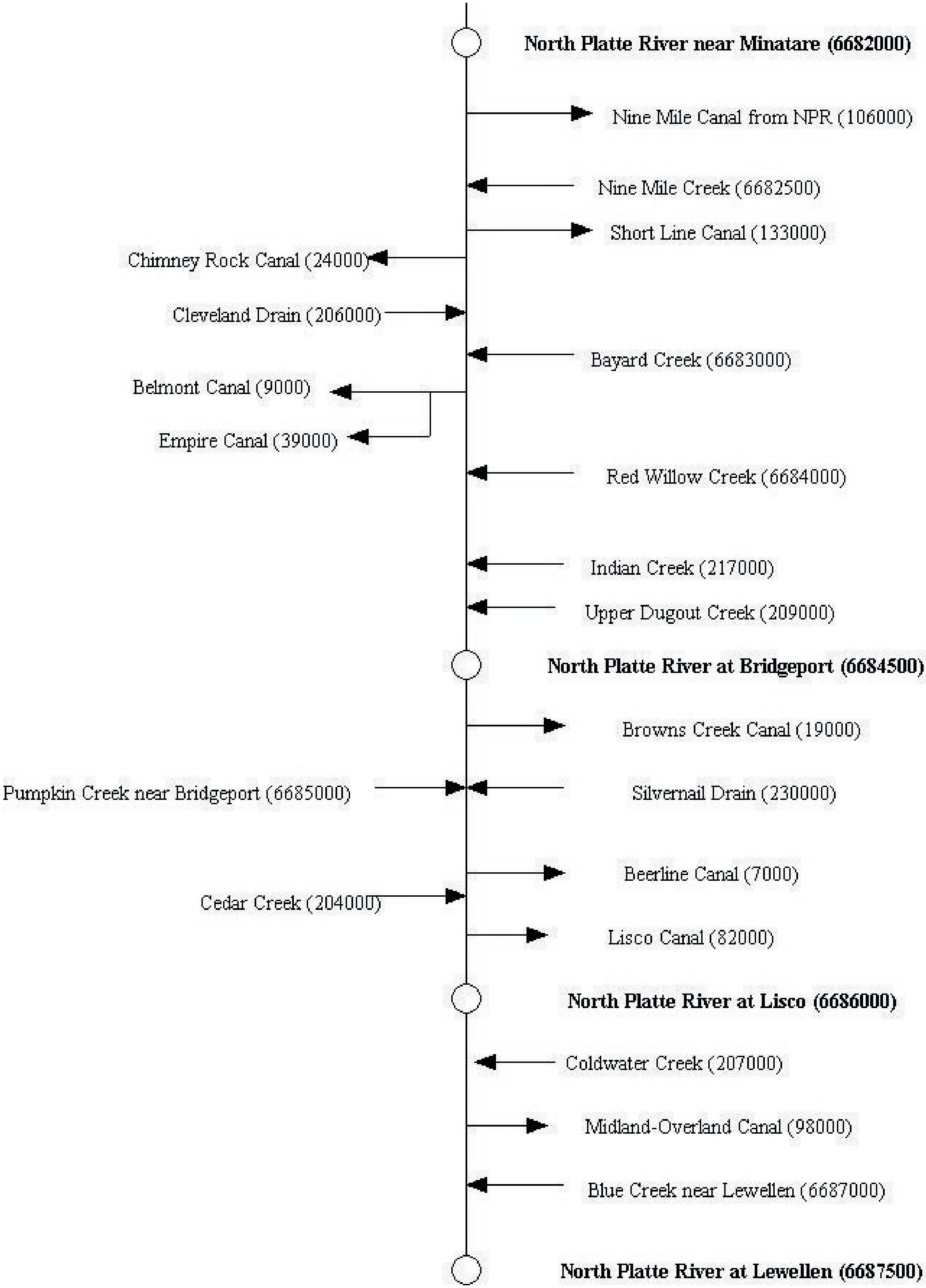
Bald	Fairfield	Lane	Scottsbluff #2
Bayard	Fanning	Melbeta	Sheep
Cleveland	Gering	Nine Mile	Dry Spottedtail
DeGraw	Horse	Red Willow	Wet Spottedtail
Upper Dugout	Indian	Scottsbluff #1	Tub Sprins, and Winters

Figure 3

North Platte River Reach Gain/Loss Computational Schematic

(State Line to Lewellen)




North Platte River near Minatare (6682000)
Nine Mile Canal from NPR (106000)
Nine Mile Creek (6682500)
Short Line Canal (133000)
Chimney Rock Canal (24000)
Cleveland Drain (206000)
Bayard Creek (6683000)
Belmont Canal (9000)
Empire Canal (39000)
Red Willow Creek (6684000)
Indian Creek (217000)
Upper Dugout Creek (209000)
North Platte River at Bridgeport (6684500)
Browns Creek Canal (19000)
Pumpkin Creek near Bridgeport (6685000)
Silvernail Drain (230000)
Beerline Canal (7000)
Cedar Creek (204000)
Lisco Canal (82000)
North Platte River at Lisco (6686000)
Coldwater Creek (207000)
Midland-Overland Canal (98000)
Blue Creek near Lewellen (6687000)
North Platte River at Lewellen (6687500)

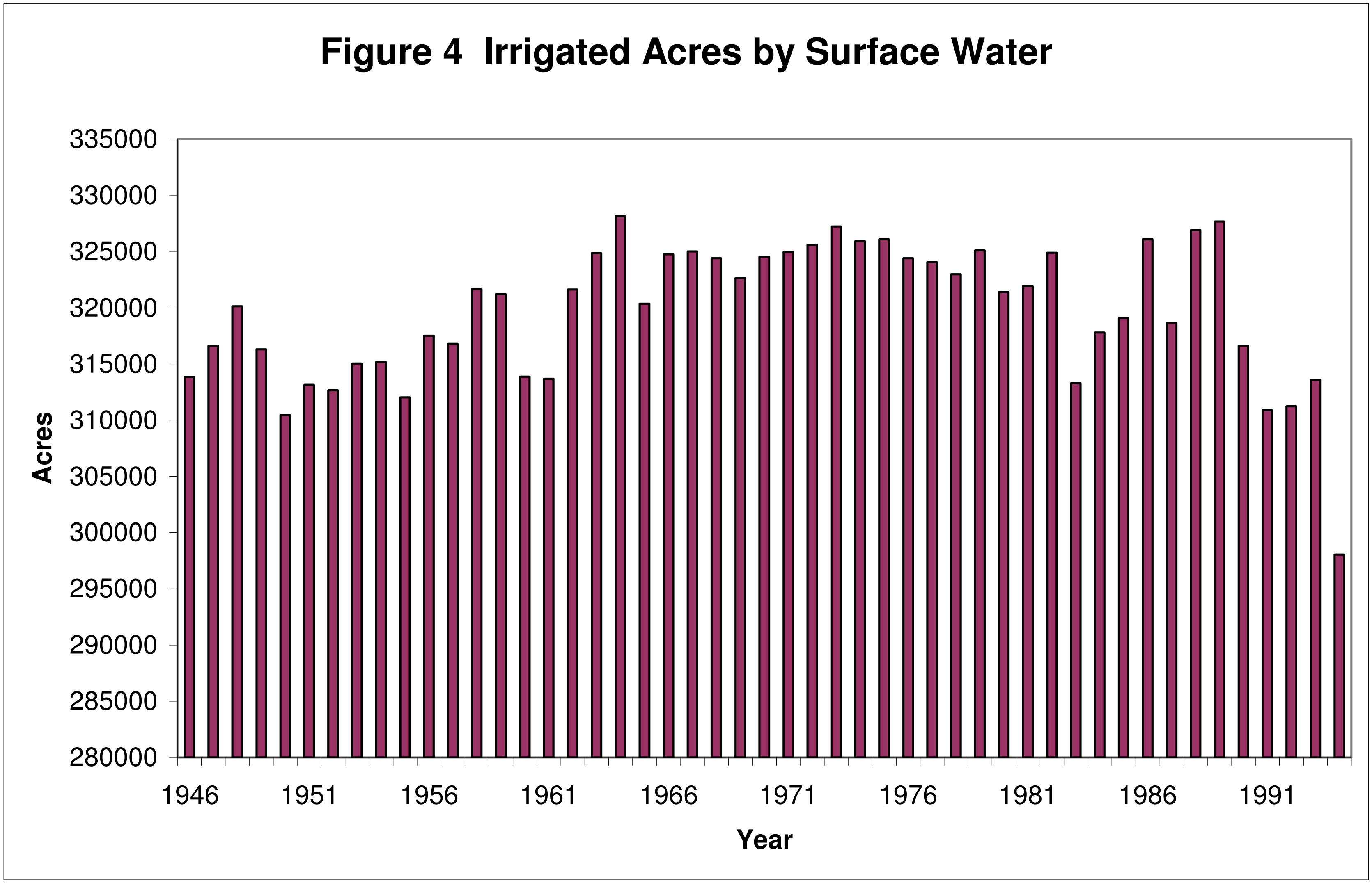


Figure 4 Irrigated Acres by Surface Water
335000
330000
325000
320000
315000
310000
305000
300000
295000
290000
285000
280000
Acres
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
Year

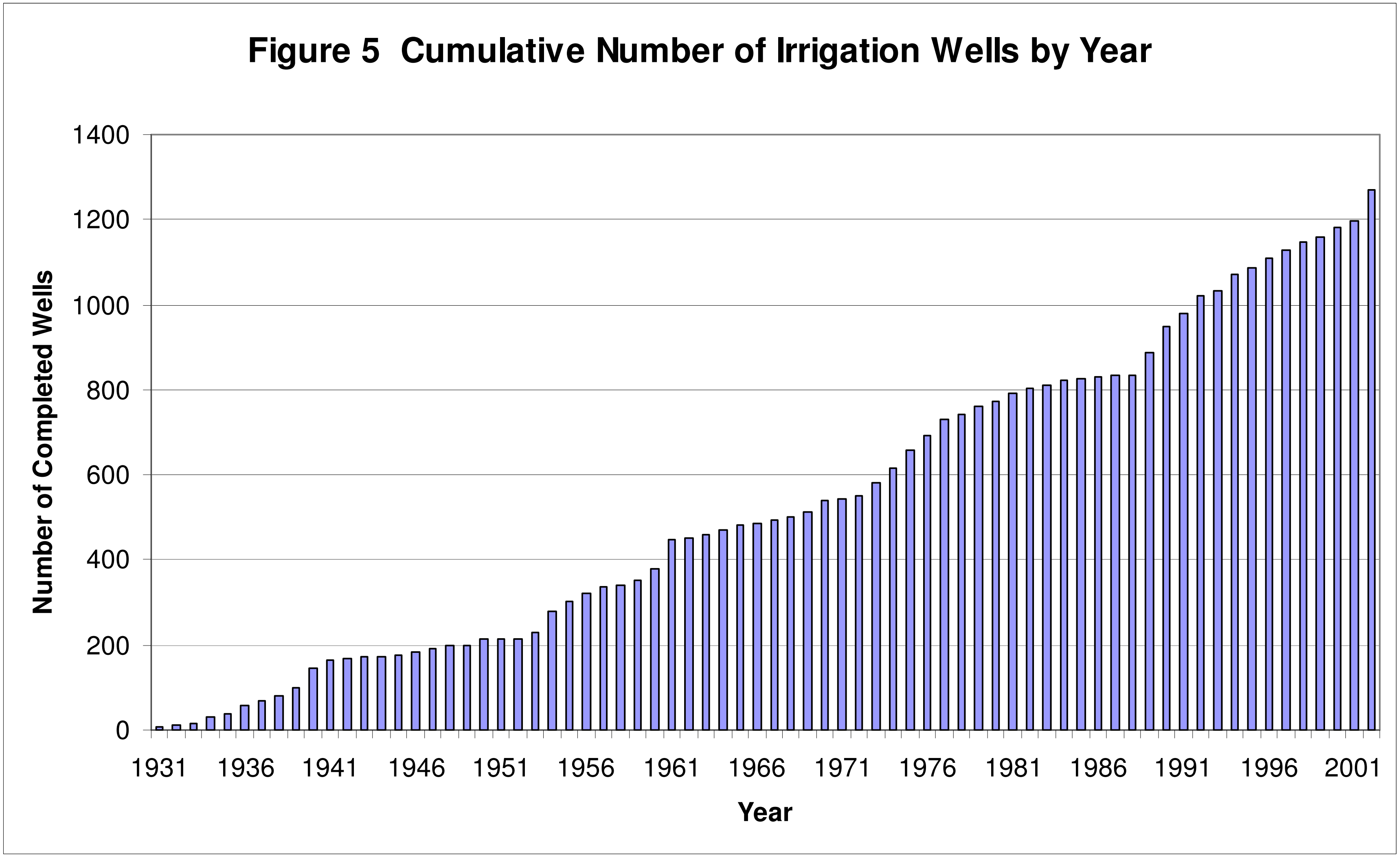
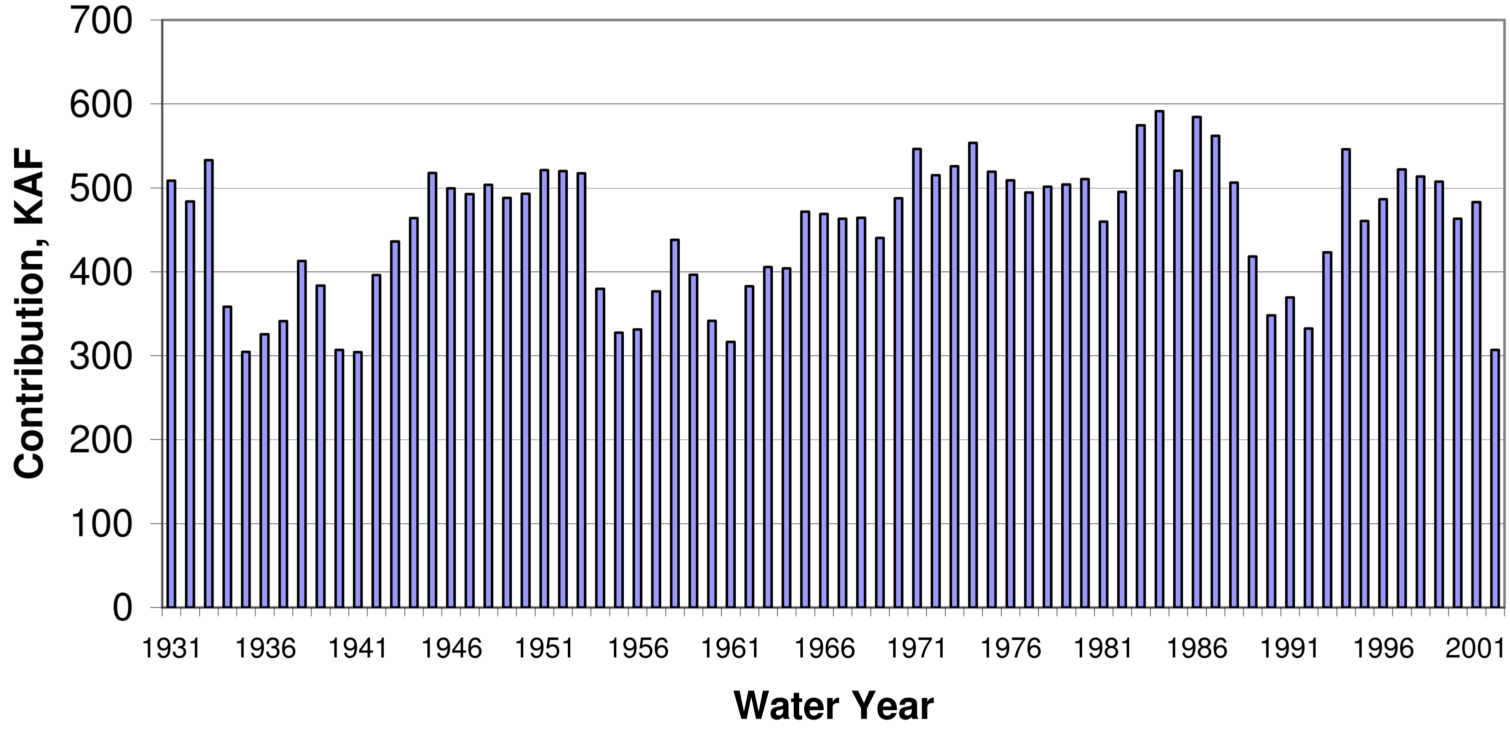


Figure 5 Cumulative Number of Irrigation Wells by Year
1400
1200
1000
800
600
400
200
0
Number of Completed Wells
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year

Figure 6 Total Contribution from Nine Tributaries

(Including both discharge into NPR and irrigation diversion)



Nine tributaries are:

Bayard Drain	Red Willow Creek	Dry Spotted Tail Creek
Gering Drain	Nine Mile Drain	Tub Springs
Horse Creek	Sheep Creek	Winters Creek

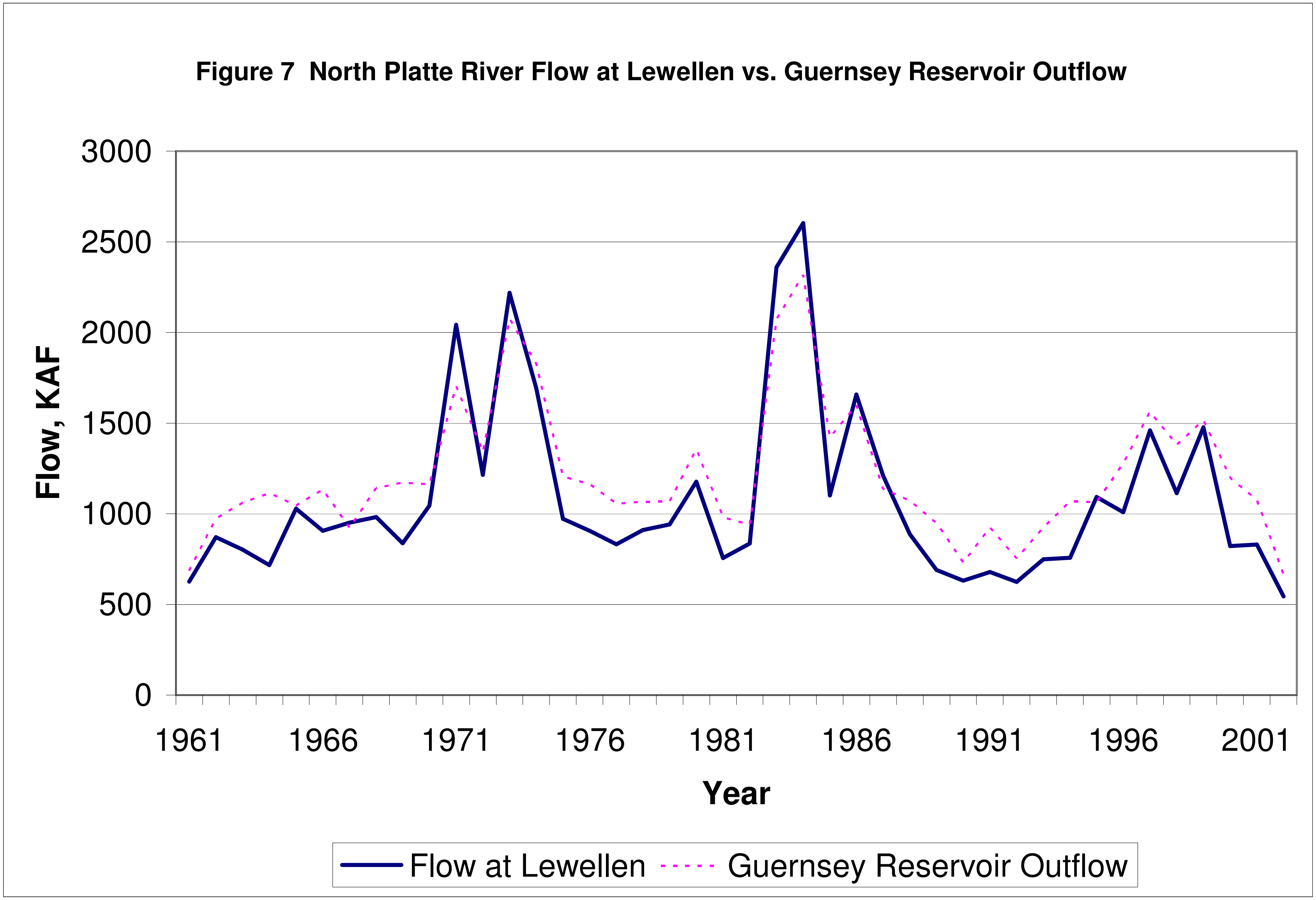
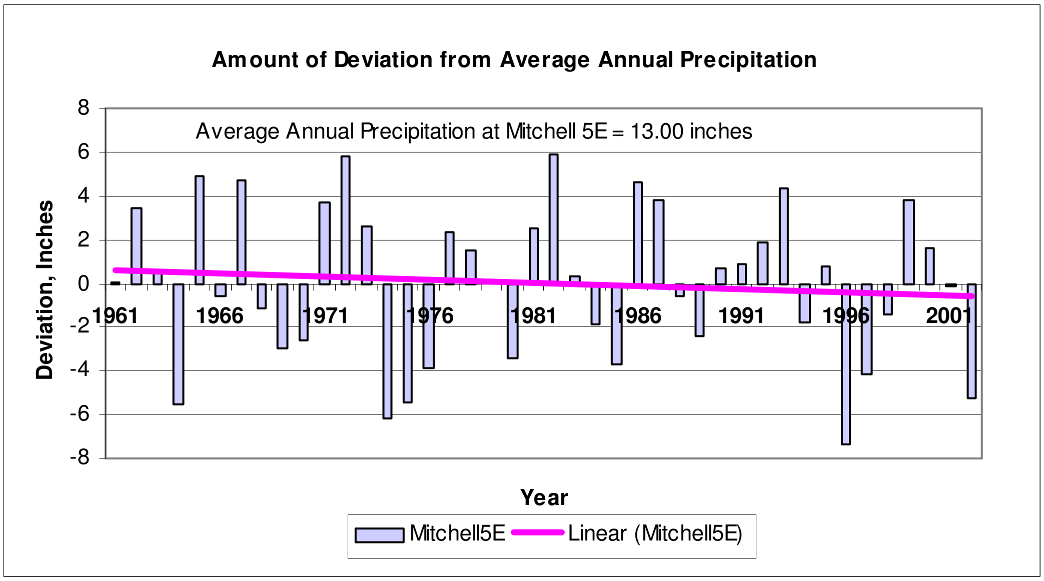
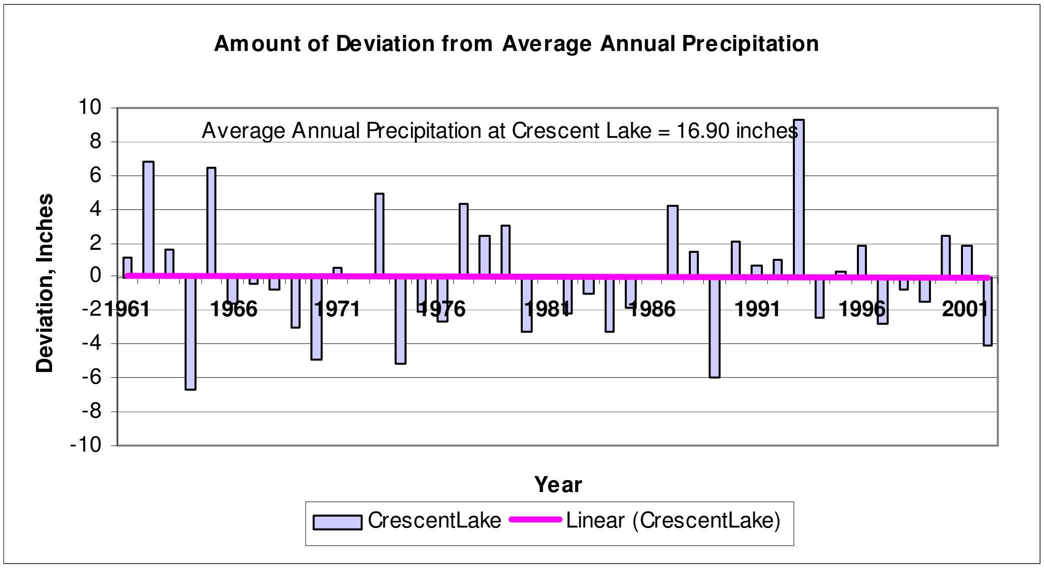


Figure 7 North Platte River Flow at Lewellen vs. Guernsey Reservoir Outflow
Flow, KAF
3000
2500
2000
1500
1000
500
0
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow at Lewellen
Guernsey Reservoir Outflow

Figure 8: Deviations from Average Annual Precipitation





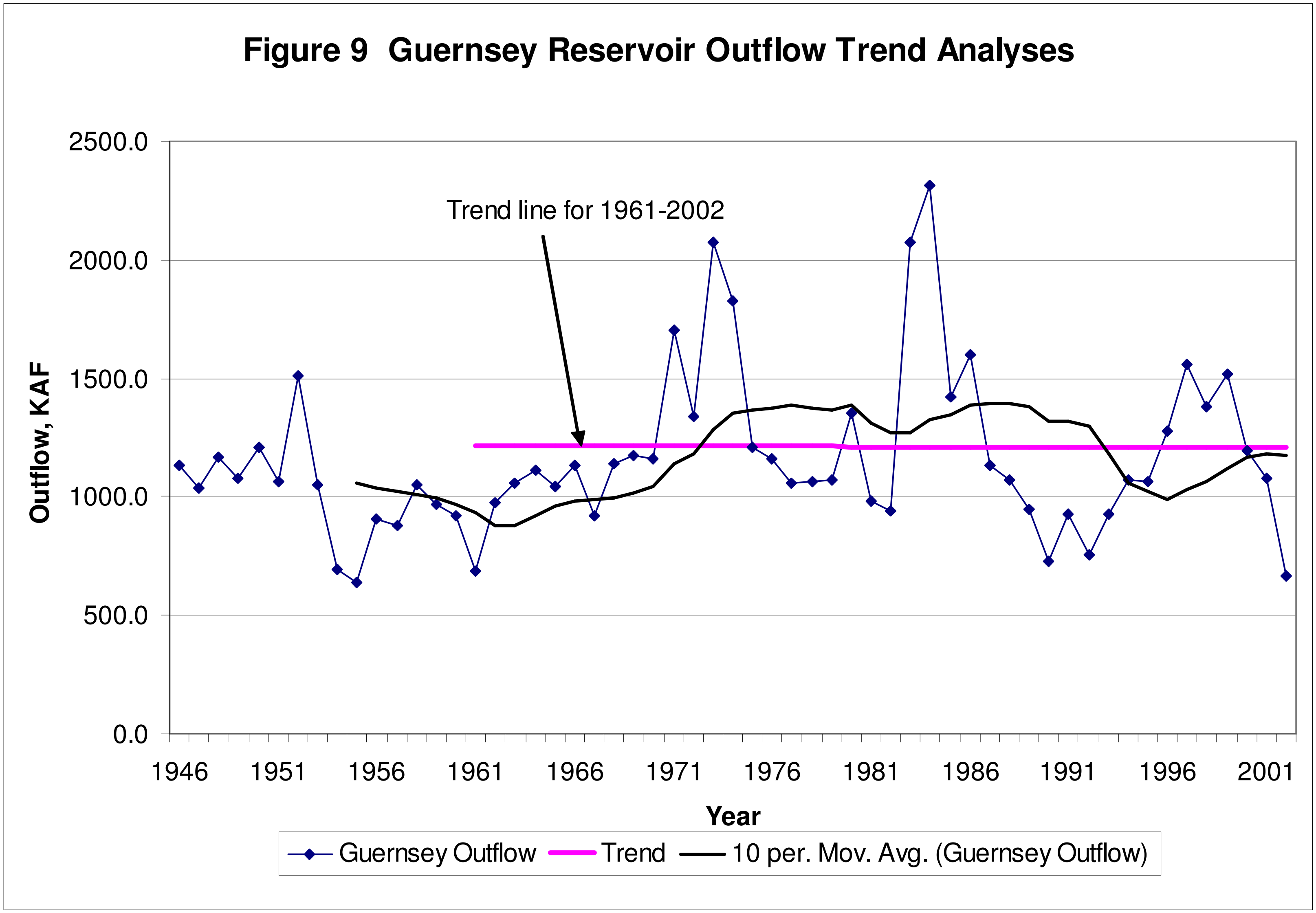


Figure 9 Guernsey Reservoir Outflow Trend Analyses
Trend line for 1961-2002
2500.0
2000.0
1500.0
1000.0
500.0
0.0
Outflow, KAF
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Guernsey Outflow
Trend
10 per. Mov. Avg. (Guernsey Outflow)

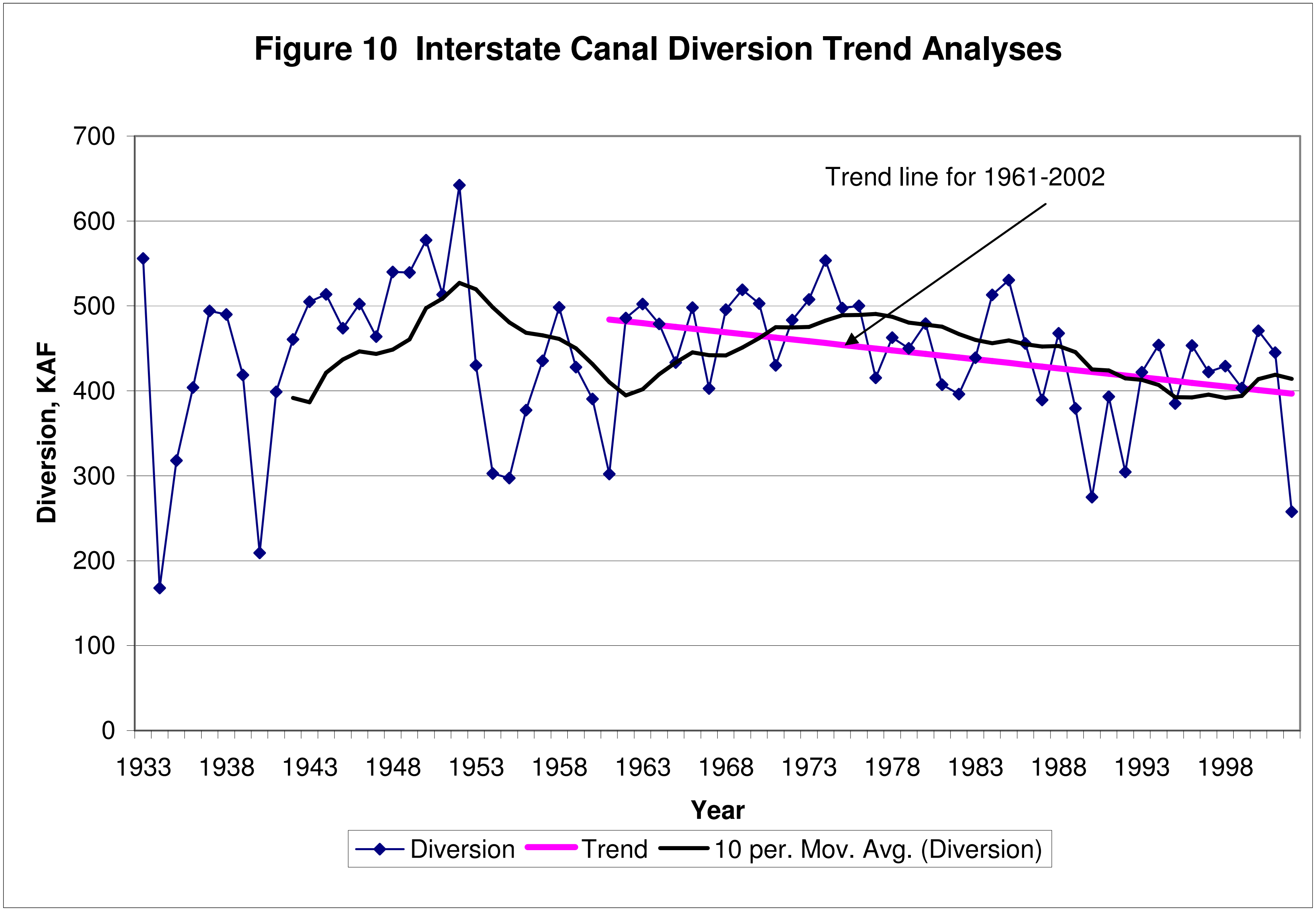


Figure 10 Interstate Canal Diversion Trend Analyses
Trend line for 1961-2002
Diversion, KAF
Year
Diversion
Trend
10 per. Mov. Avg. (Diversion)
0
100
200
300
400
500
600
700
1933
1938
1943
1948
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998

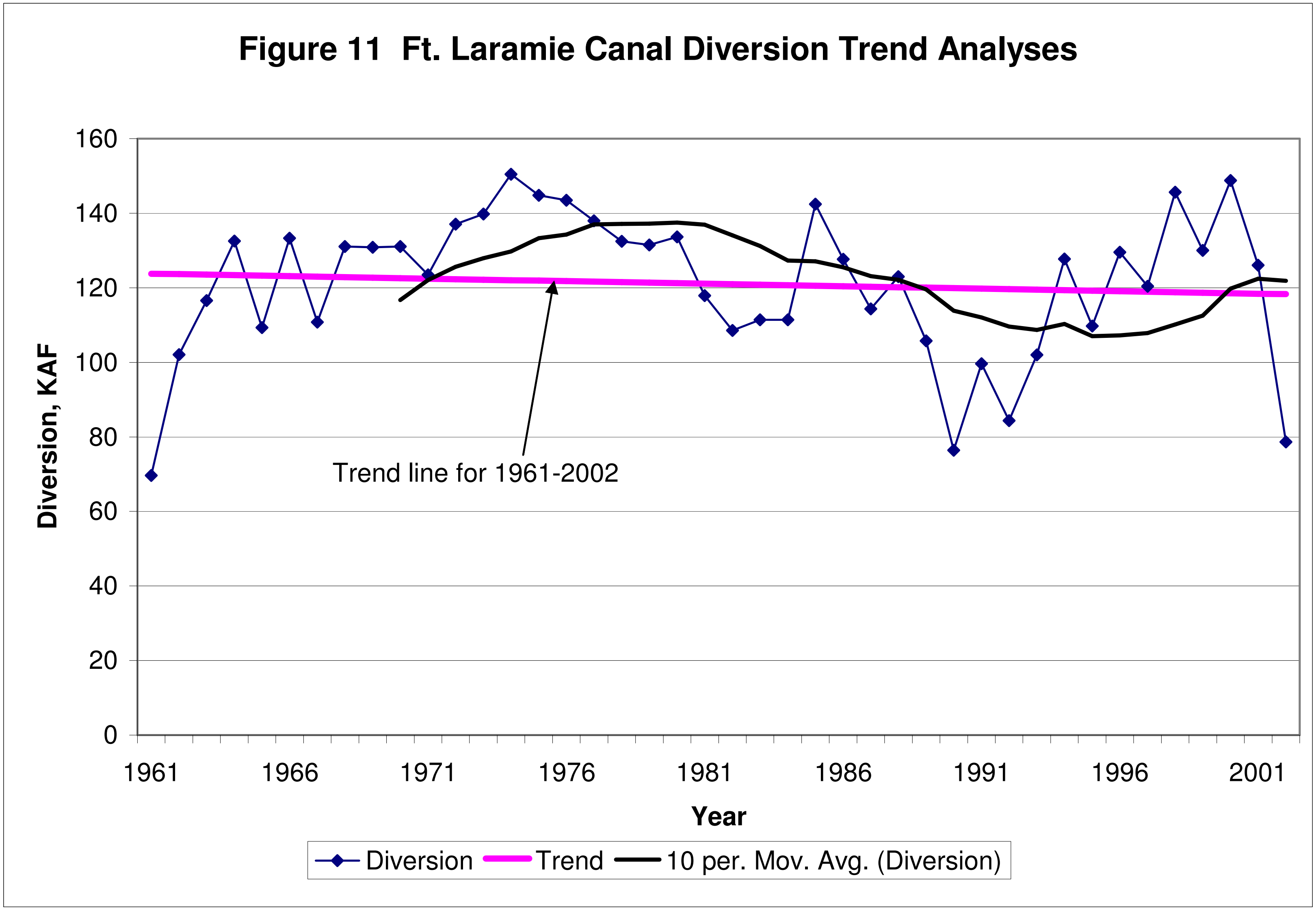


Figure 11 Ft. Laramie Canal Diversion Trend Analyses
160
140
120
100
80
60
40
20
0
Diversion, KAF
Trend line for 1961-2002
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Diversion
Trend
10 per. Mov. Avg. (Diversion)

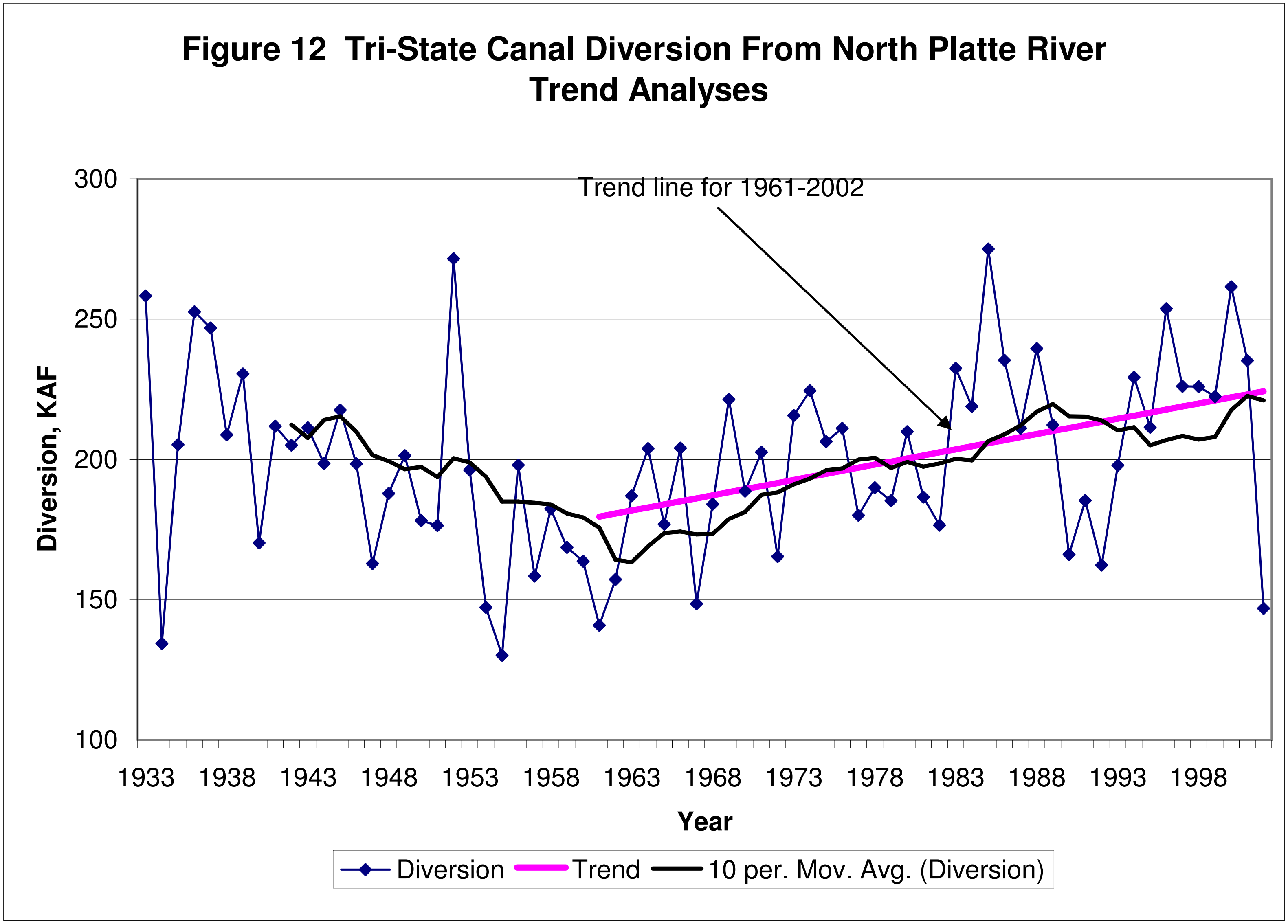


Figure 12 Tri-State Canal Diversion From North Platte River
Trend Analyses
Trend line for 1961-2002
300
250
200
150
100
Diversion, KAF
1933
1938
1943
1948
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
Year
Diversion
Trend
10 per. Mov. Avg. (Diversion)

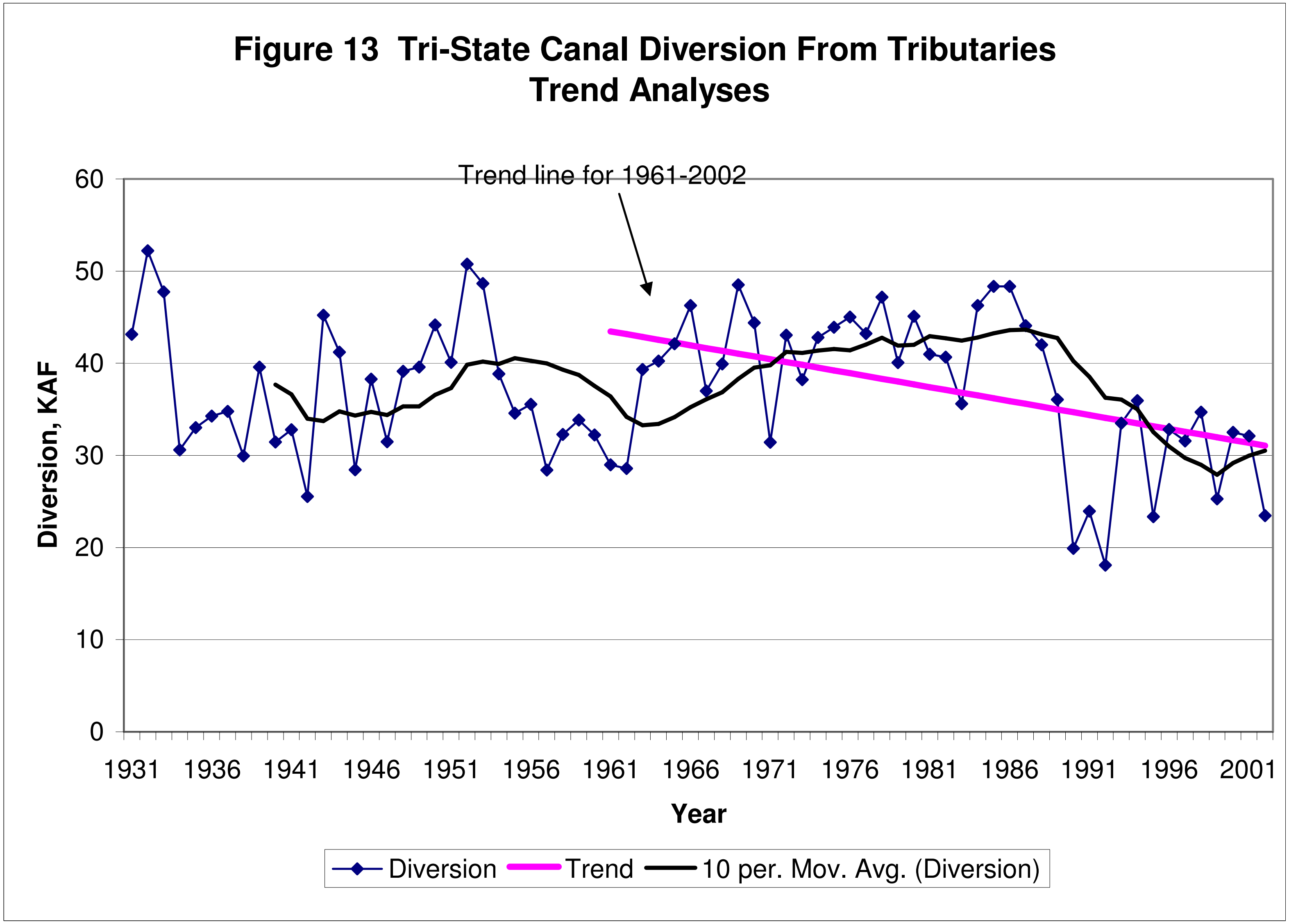


Figure 13 Tri-State Canal Diversion From Tributaries
Trend Analyses
Trend line for 1961-2002
60
50
40
30
20
10
0
Diversion, KAF
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Diversion
Trend
10 per. Mov. Avg. (Diversion)

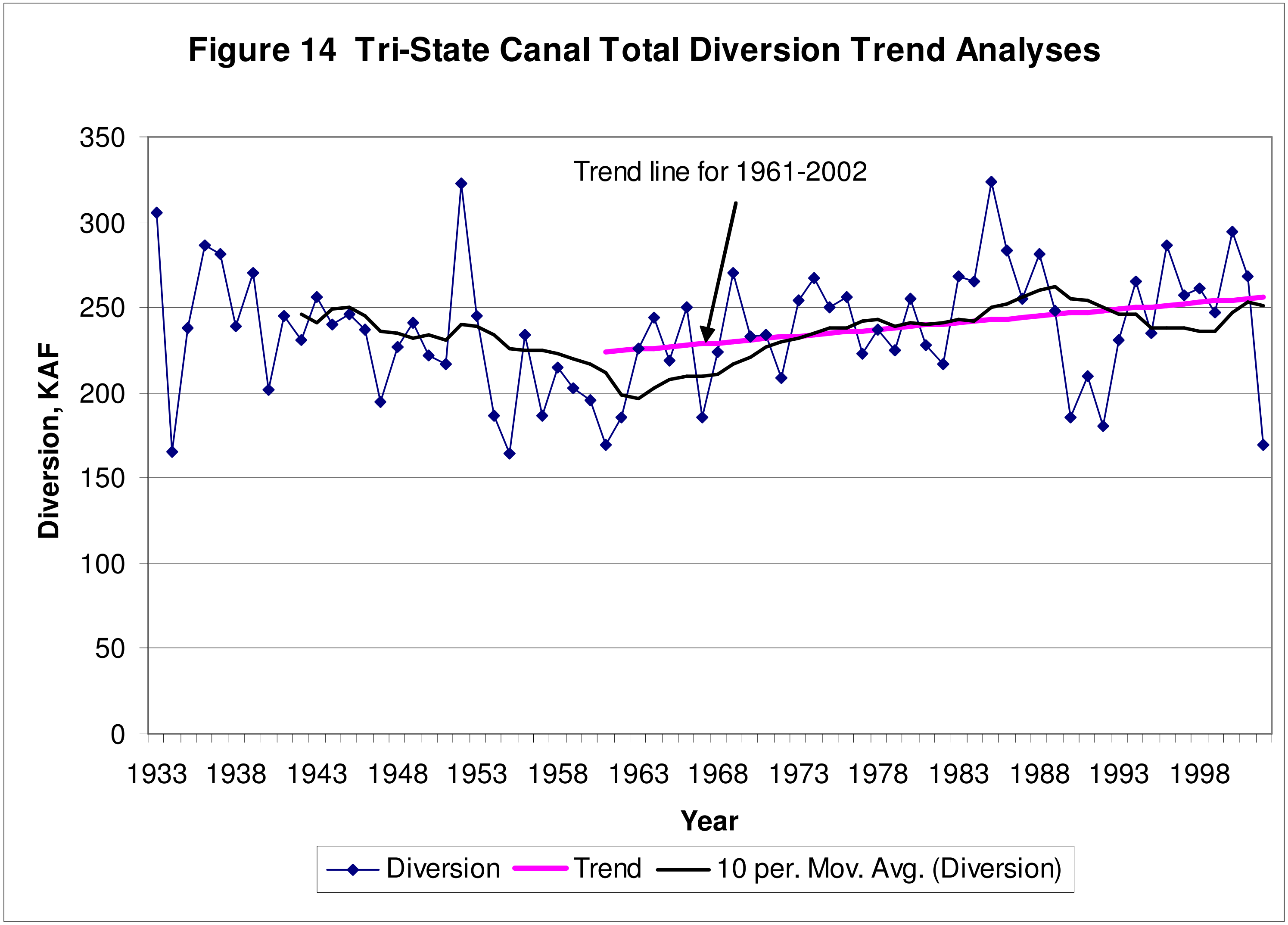


Figure 14 Tri-State Canal Total Diversion Trend Analyses
Trend line for 1961-2002
350
300
250
200
150
100
50
0
Diversion, KAF
1933 1938 1943 1948 1953 1958 1963 1968 1973 1978 1983 1988 1993 1998
Year
Diversion
Trend
10 per. Mov. Avg. (Diversion)

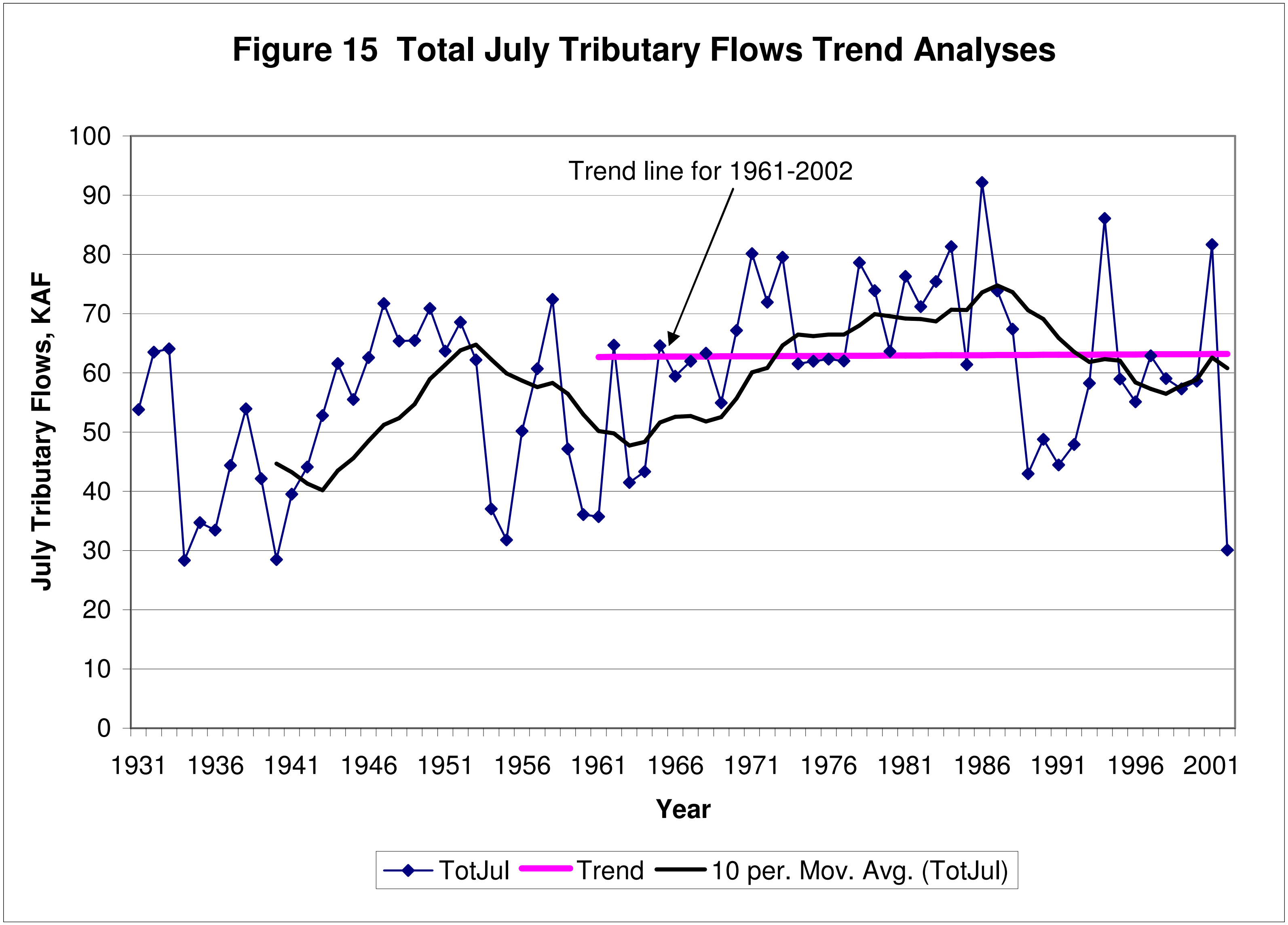


Figure 15 Total July Tributary Flows Trend Analyses
Trend line for 1961-2002
July Tributary Flows, KAF
Year
100
90
80
70
60
50
40
30
20
10
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
TotJul
Trend
10 per. Mov. Avg. (TotJul)

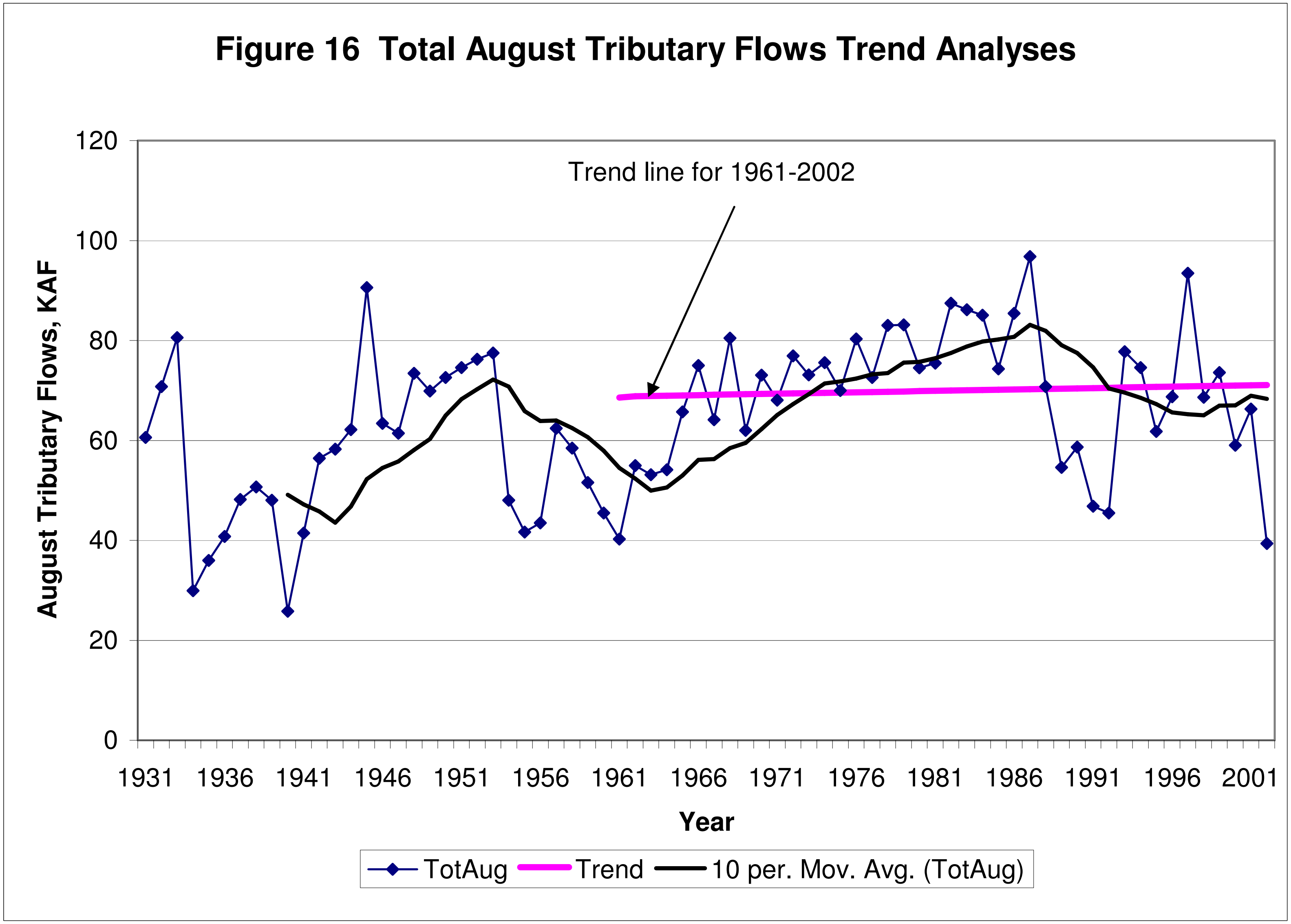


Figure 16 Total August Tributary Flows Trend Analyses
Trend line for 1961-2002
August Tributary Flows, KAF
120
100
80
60
40
20
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotAug
Trend
10 per. Mov. Avg. (TotAug)

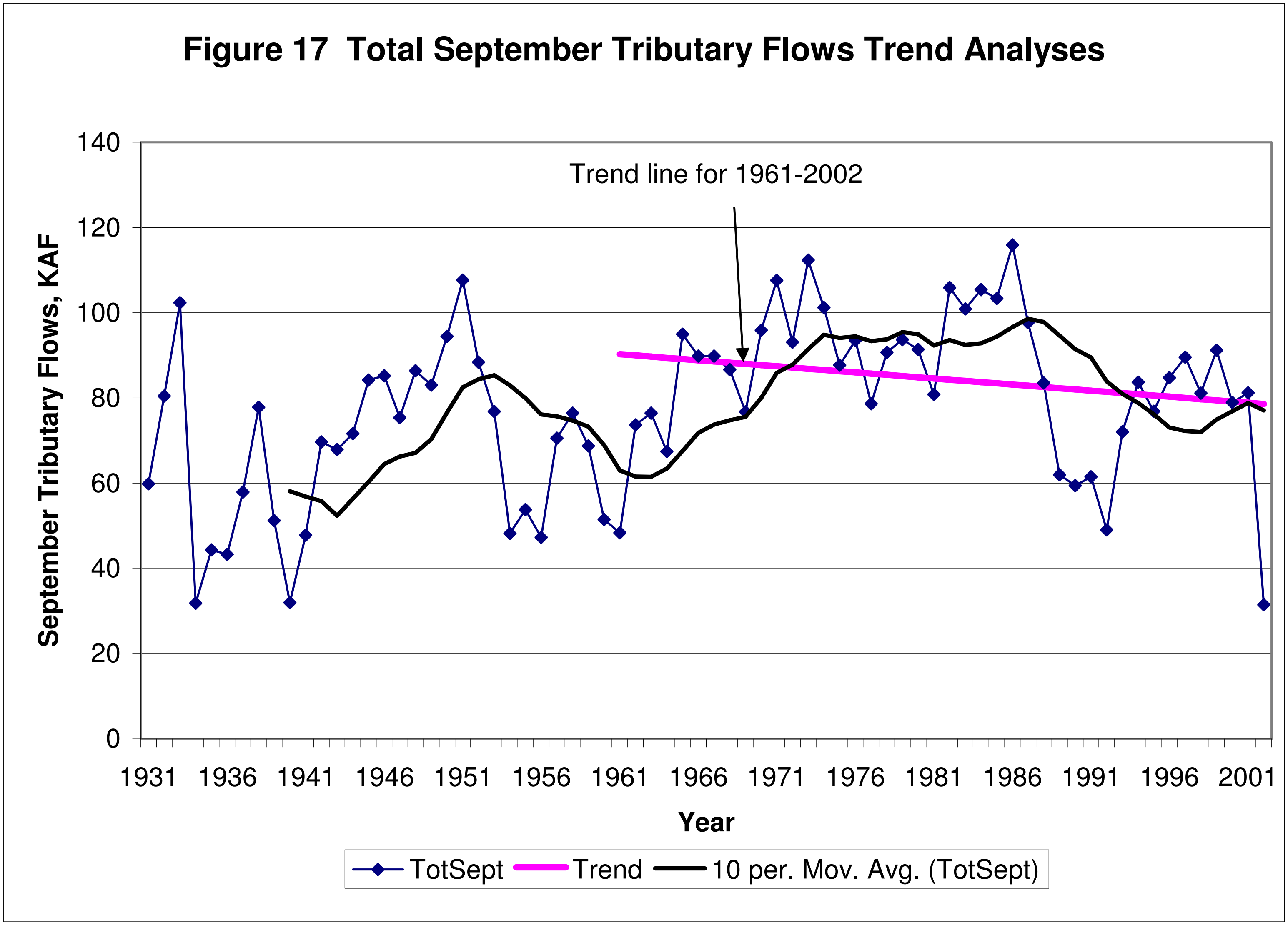


Figure 17 Total September Tributary Flows Trend Analyses
Trend line for 1961-2002
September Tributary Flows, KAF
0
20
40
60
80
100
120
140
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotSept
Trend
10 per. Mov. Avg. (TotSept)

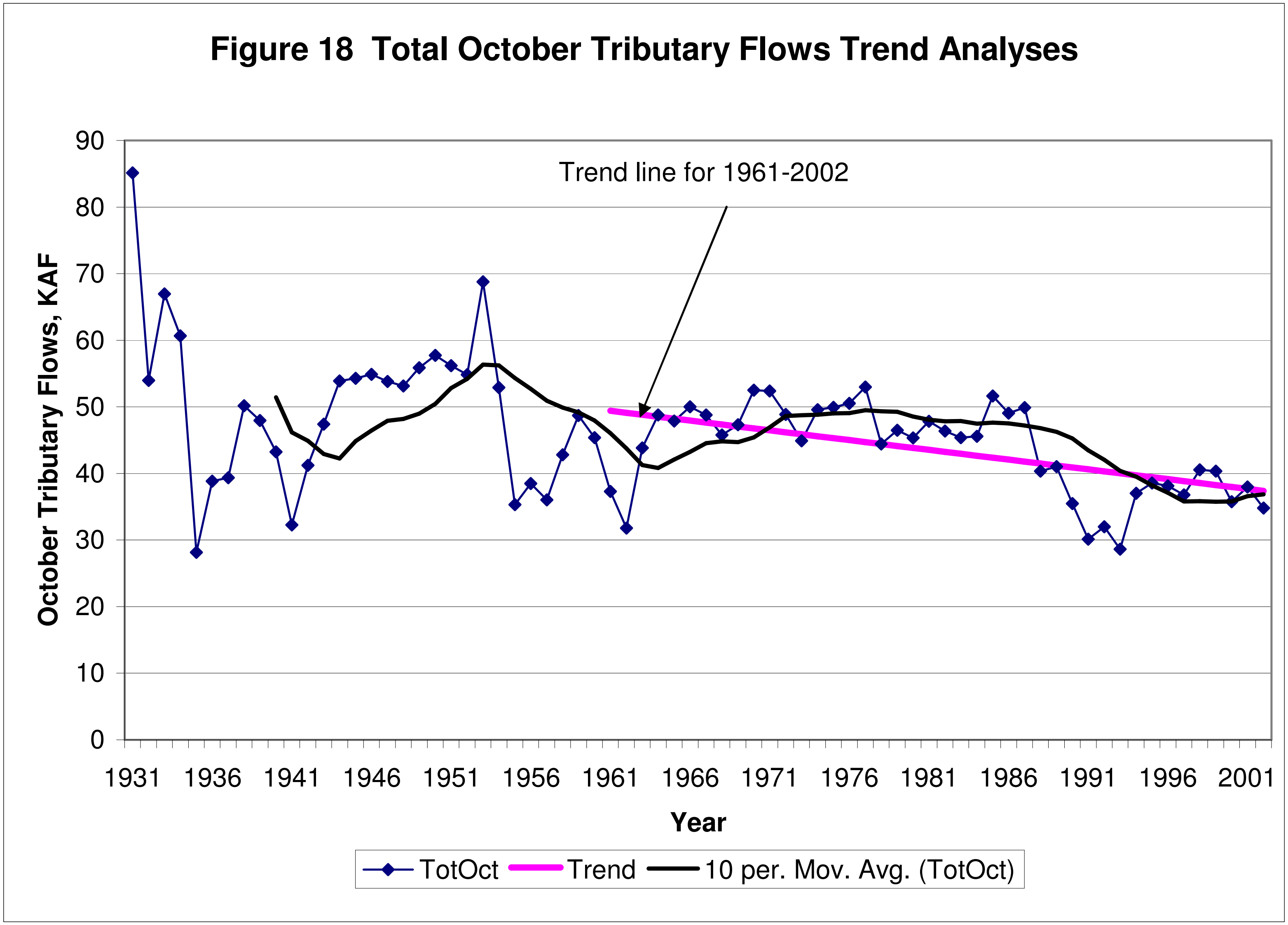


Figure 18 Total October Tributary Flows Trend Analyses
Trend line for 1961-2002
October Tributary Flows, KAF
0
10
20
30
40
50
60
70
80
90
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotOct
Trend
10 per. Mov. Avg. (TotOct)

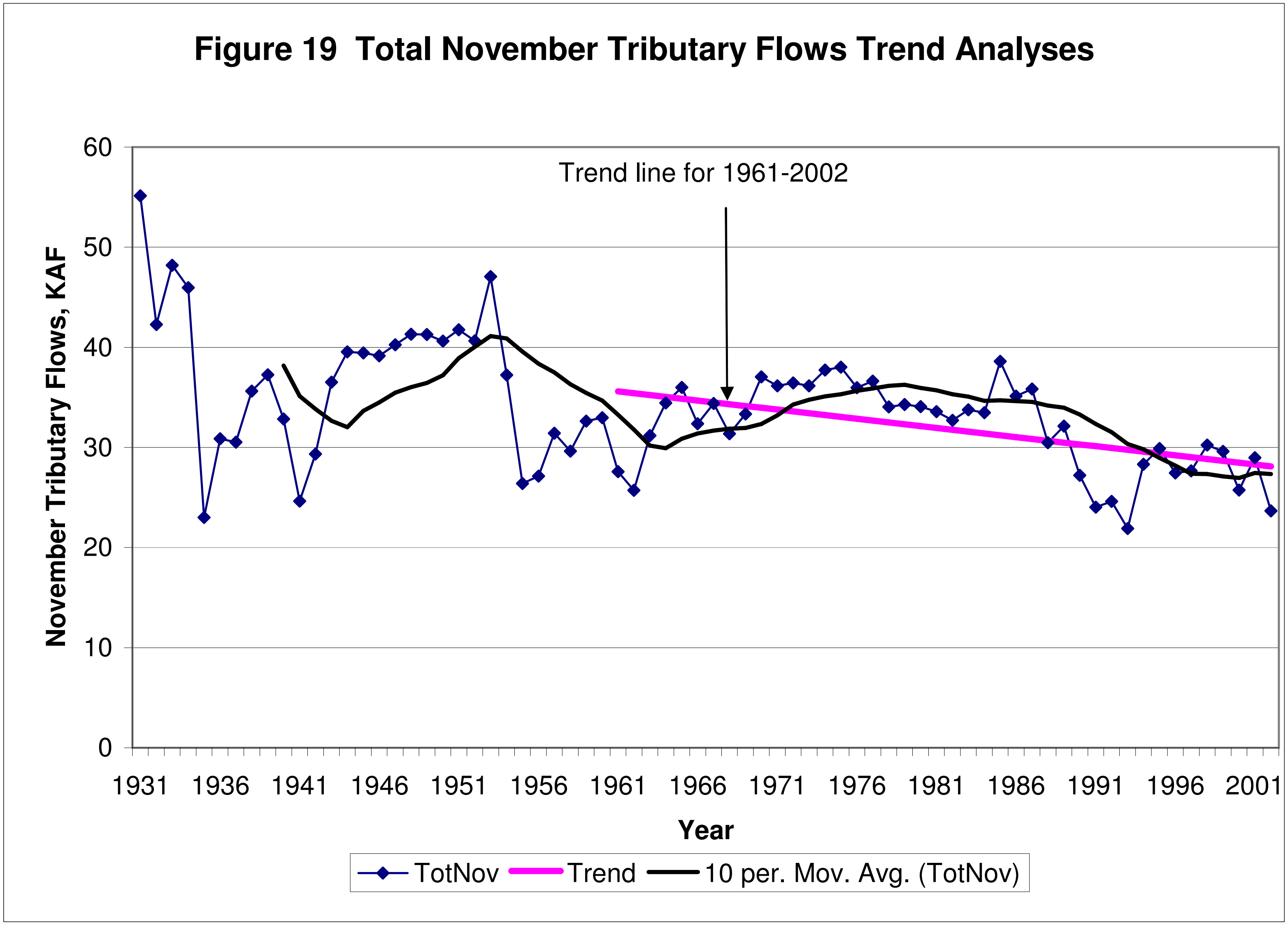


Figure 19 Total November Tributary Flows Trend Analyses
Trend line for 1961-2002
November Tributary Flows, KAF
60
50
40
30
20
10
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotNov
Trend
10 per. Mov. Avg. (TotNov)

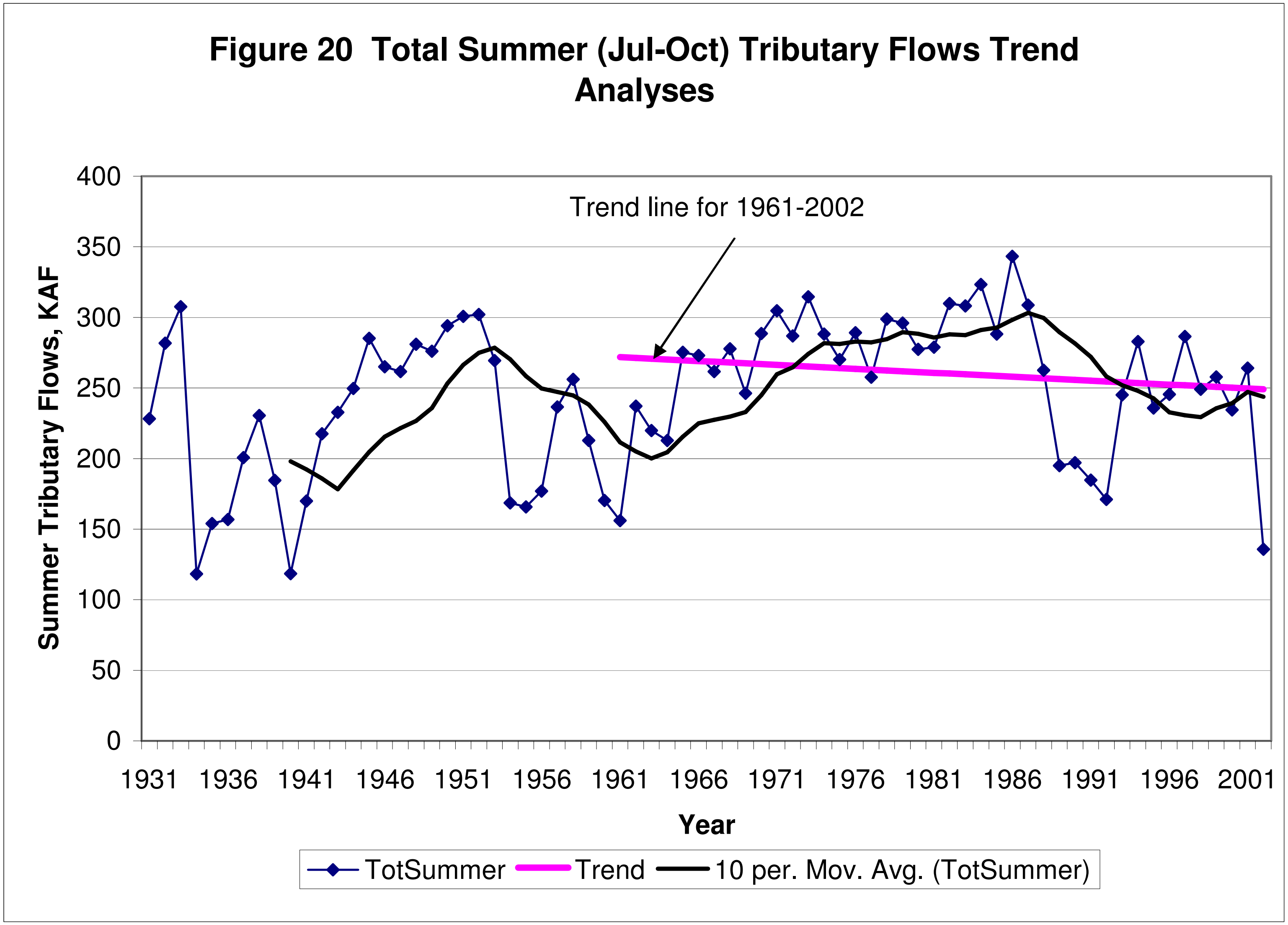


Figure 20 Total Summer (Jul-Oct) Tributary Flows Trend Analyses
Trend line for 1961-2002
Summer Tributary Flows, KAF
400
350
300
250
200
150
100
50
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotSummer
Trend
10 per. Mov. Avg. (TotSummer)

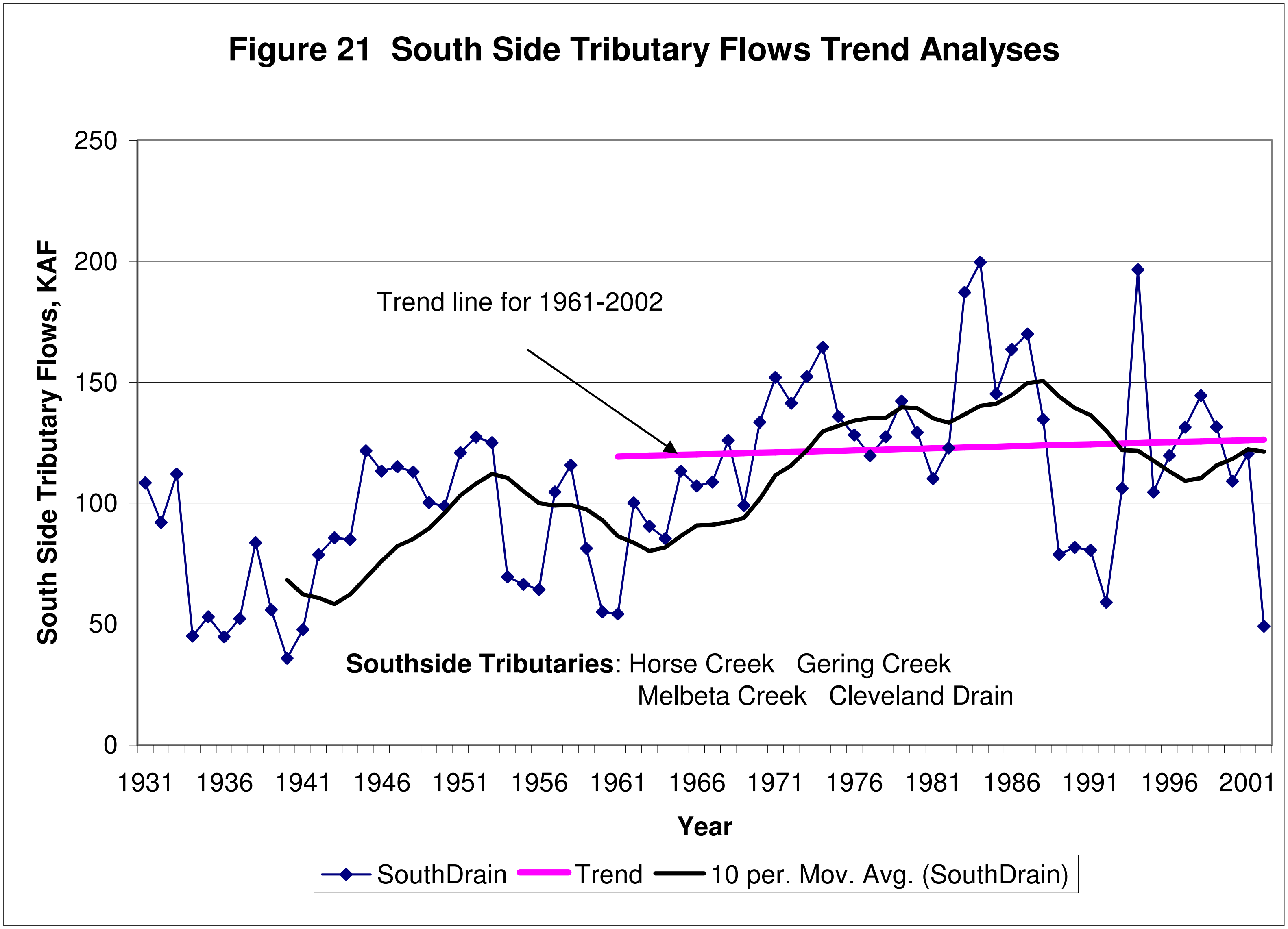


Figure 21 South Side Tributary Flows Trend Analyses
South Side Tributary Flows, KAF
250
200
150
100
50
0
Trend line for 1961-2002
Southside Tributaries: Horse Creek Gering Creek
Melbeta Creek Cleveland Drain
1931 1936 1941 1946 1951 1956 1961 1966 1971 1976 1981 1986 1991 1996 2001
Year
SouthDrain
Trend
10 per. Mov. Avg. (SouthDrain)

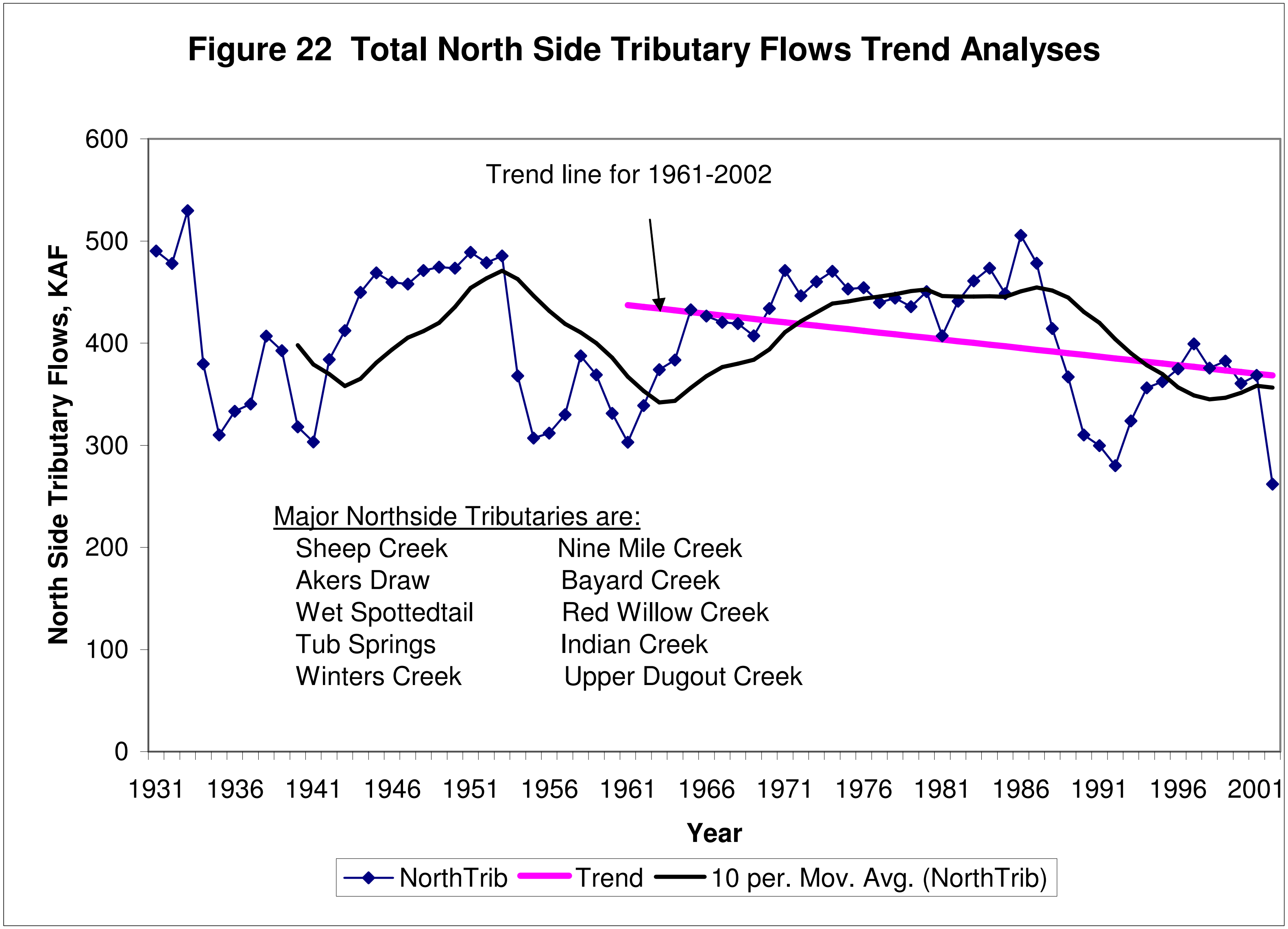


Figure 22 Total North Side Tributary Flows Trend Analyses
Trend line for 1961-2002
North Side Tributary Flows, KAF
600
500
400
300
200
100
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Major Northside Tributaries are:
Sheep Creek
Akers Draw
Wet Spottedtail
Tub Springs
Winters Creek
Nine Mile Creek
Bayard Creek
Red Willow Creek
Indian Creek
Upper Dugout Creek
NorthTrib
Trend
10 per. Mov. Avg. (NorthTrib)

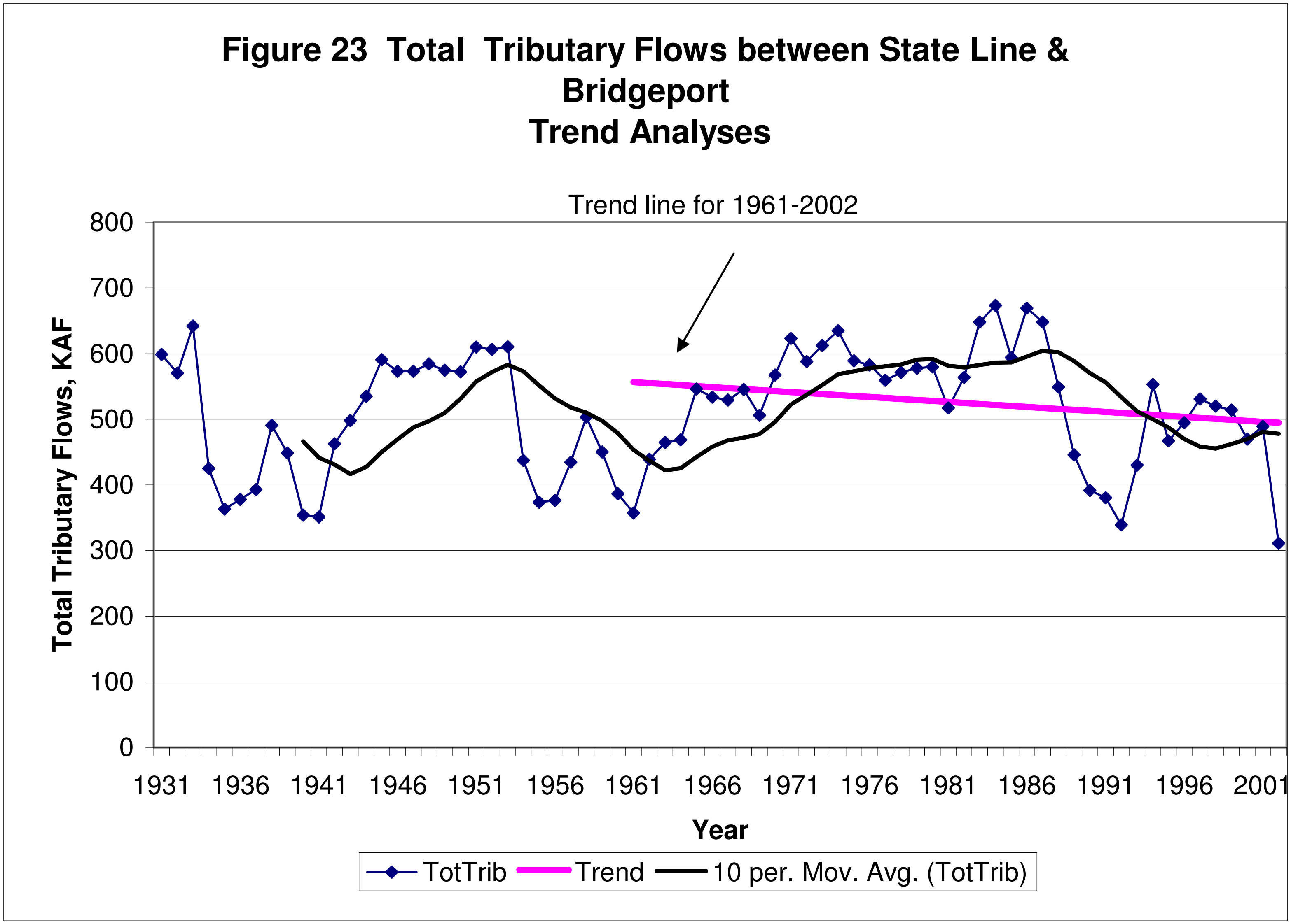


Figure 23 Total Tributary Flows between State Line & Bridgeport
Trend Analyses
Trend line for 1961-2002
Total Tributary Flows, KAF
800
700
600
500
400
300
200
100
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotTrib
Trend
10 per. Mov. Avg. (TotTrib)

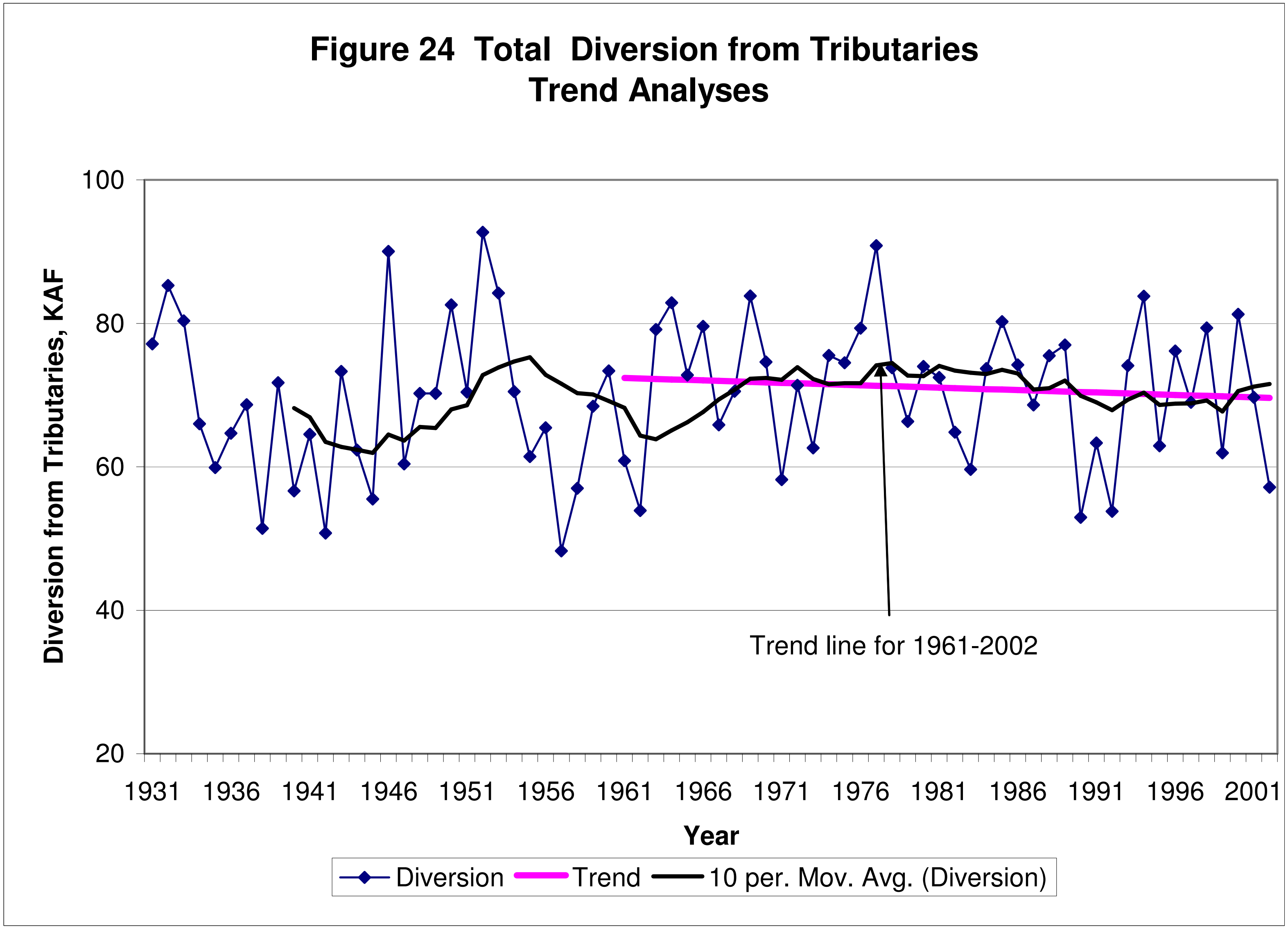


Figure 24 Total Diversion from Tributaries
Trend Analyses
Diversion from Tributaries, KAF
100
80
60
40
20
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Trend line for 1961-2002
Diversion
Trend
10 per. Mov. Avg. (Diversion)

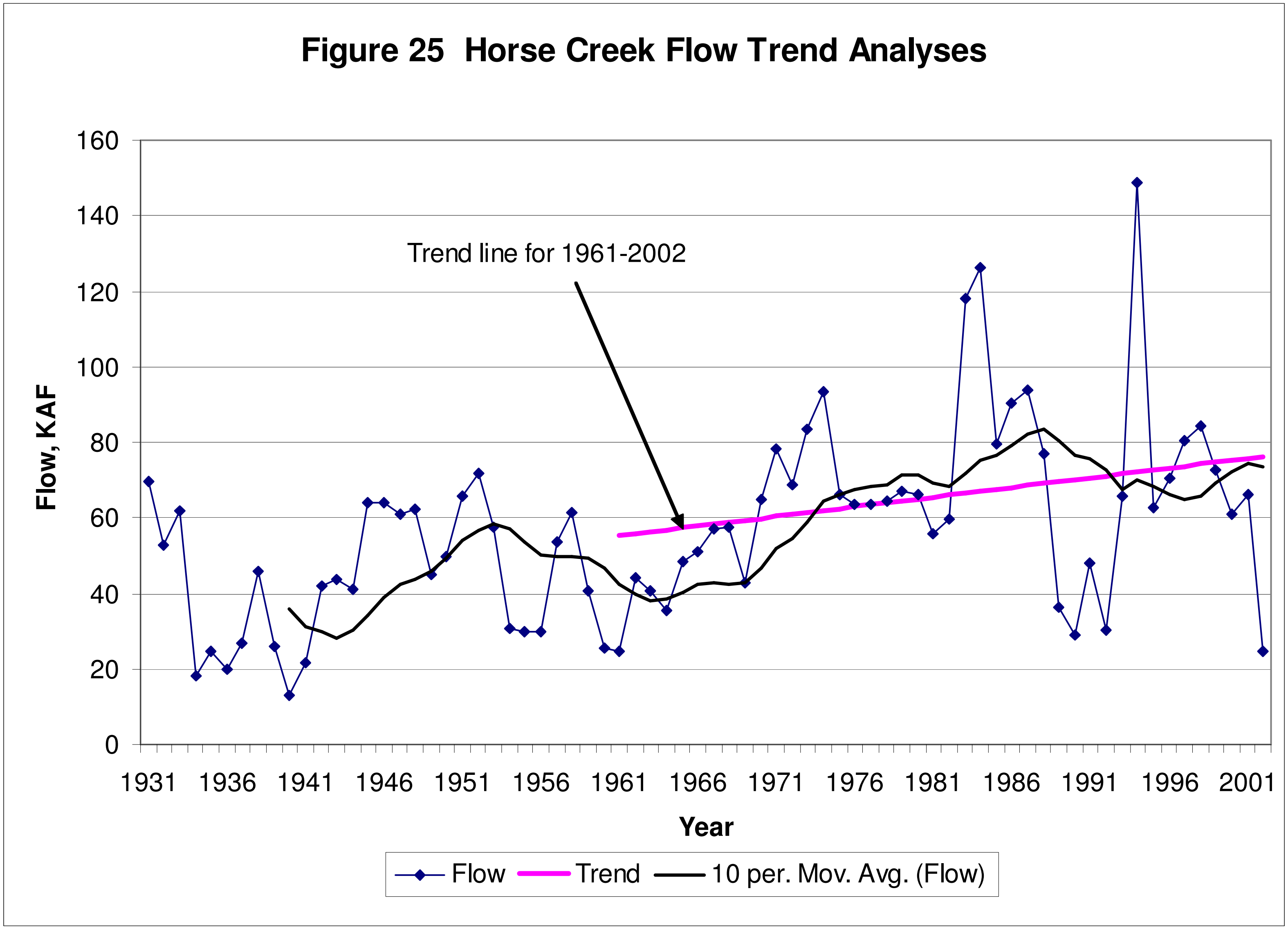


Figure 25 Horse Creek Flow Trend Analyses
Trend line for 1961-2002
Flow, KAF
160
140
120
100
80
60
40
20
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

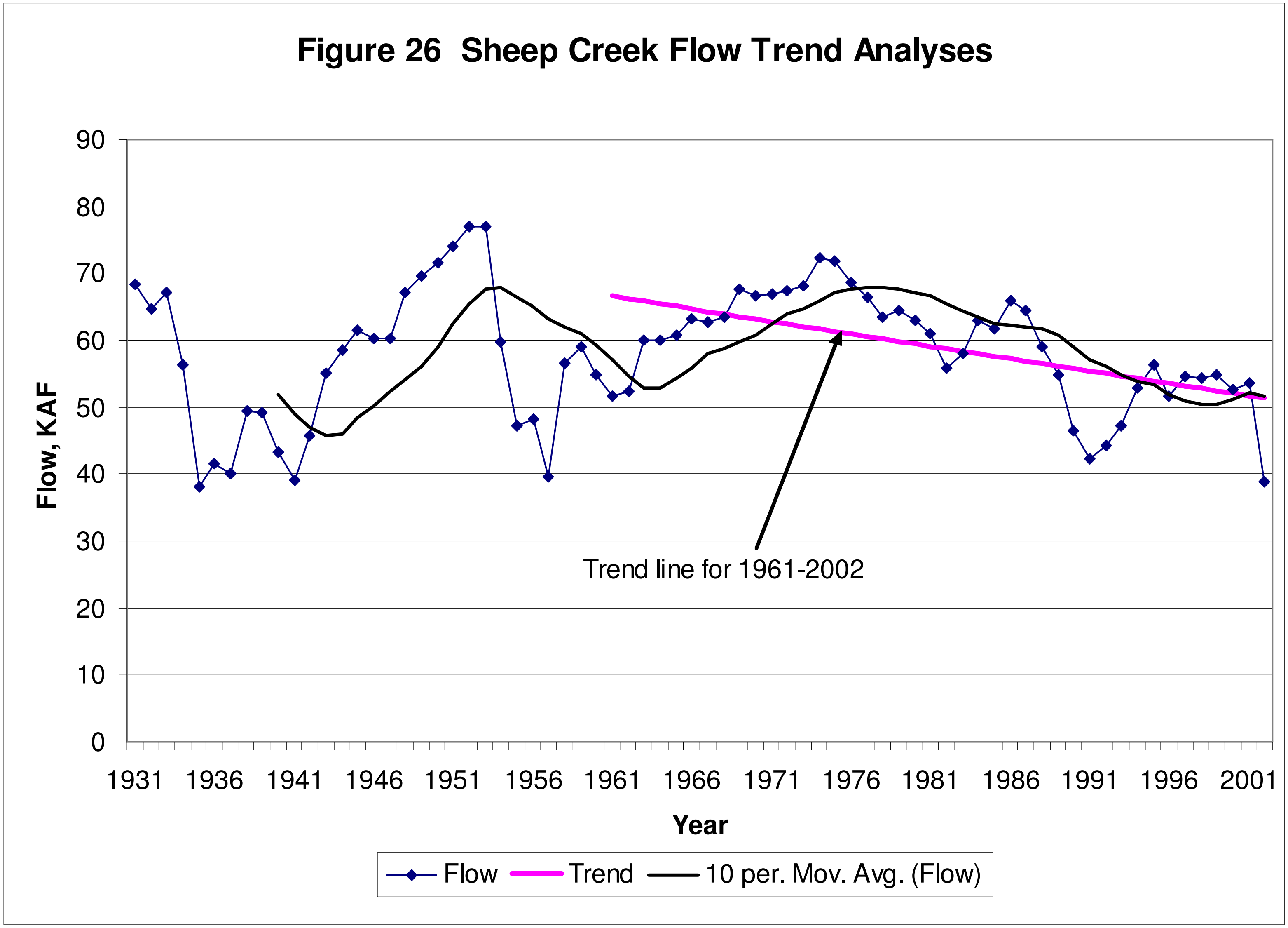


Figure 26 Sheep Creek Flow Trend Analyses
Flow, KAF
90
80
70
60
50
40
30
20
10
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Trend line for 1961-2002
Flow
Trend
10 per. Mov. Avg. (Flow)

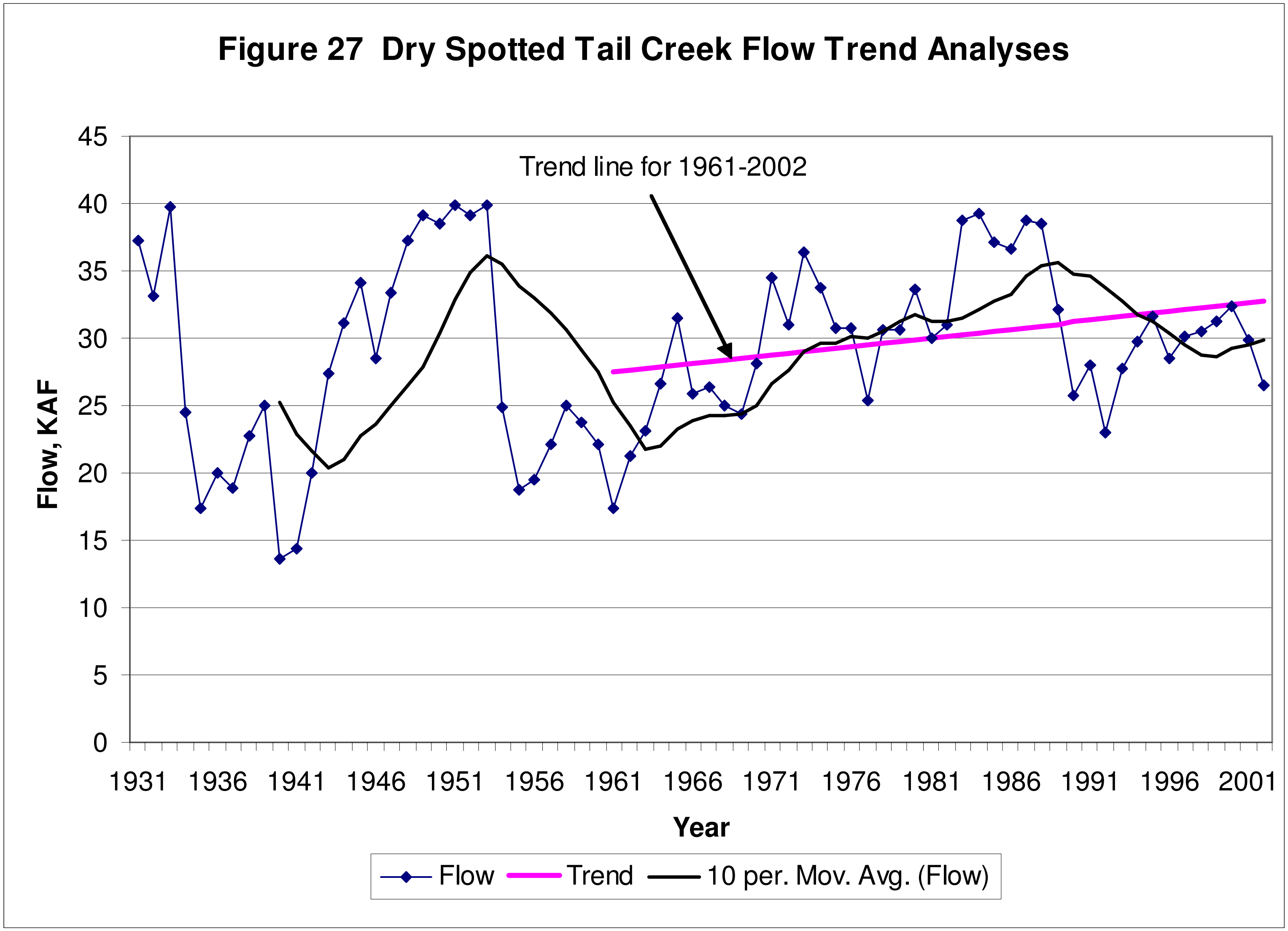


Figure 27 Dry Spotted Tail Creek Flow Trend Analyses
Trend line for 1961-2002
Flow, KAF
45
40
35
30
25
20
15
10
5
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

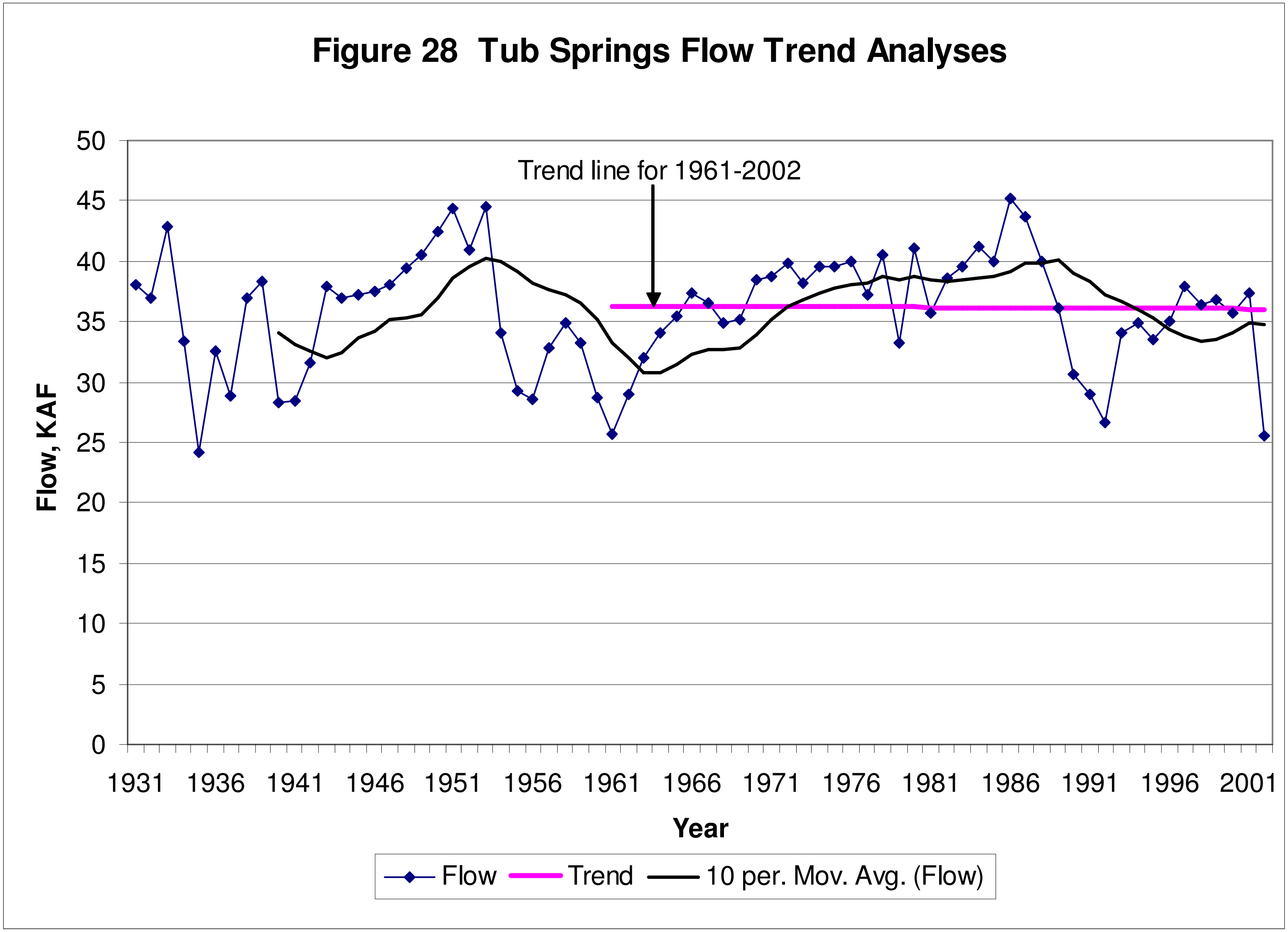


Figure 28 Tub Springs Flow Trend Analyses
Trend line for 1961-2002
50
45
40
35
30
25
20
15
10
5
0
Flow, KAF
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

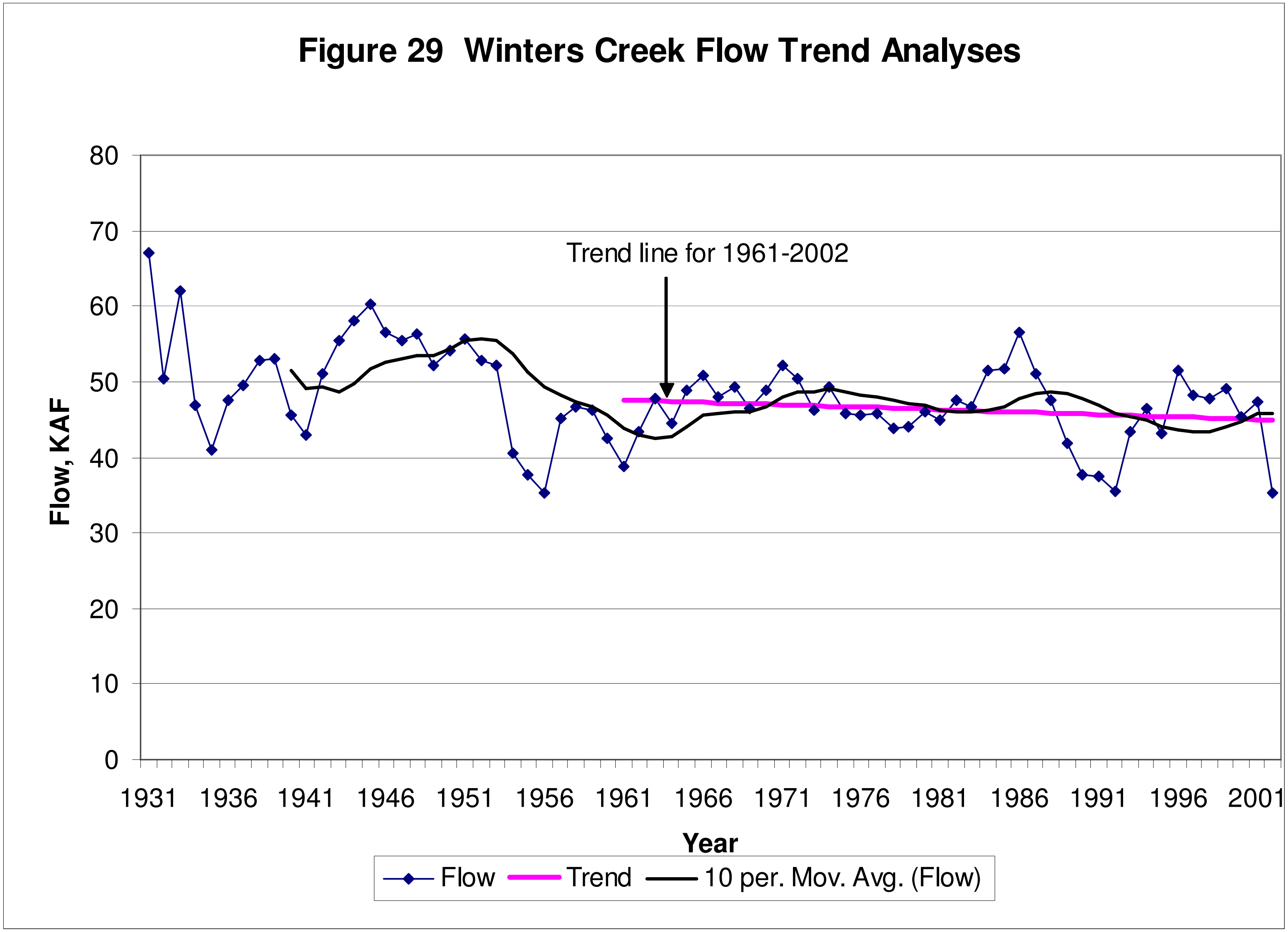


Figure 29 Winters Creek Flow Trend Analyses
Trend line for 1961-2002
Flow, KAF
80
70
60
50
40
30
20
10
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

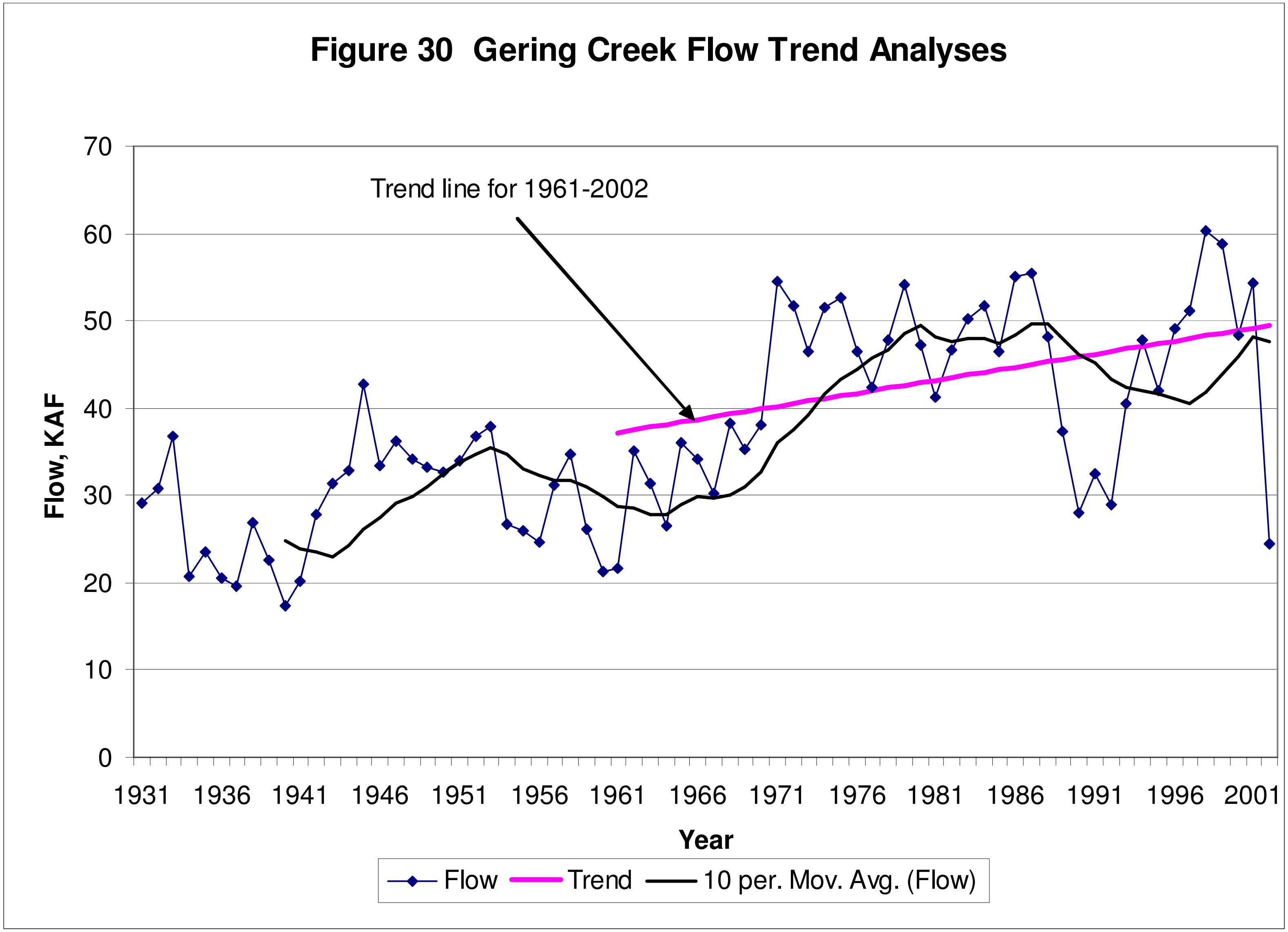


Figure 30 Gering Creek Flow Trend Analyses
Trend line for 1961-2002
70
60
50
40
30
20
10
0
Flow, KAF
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

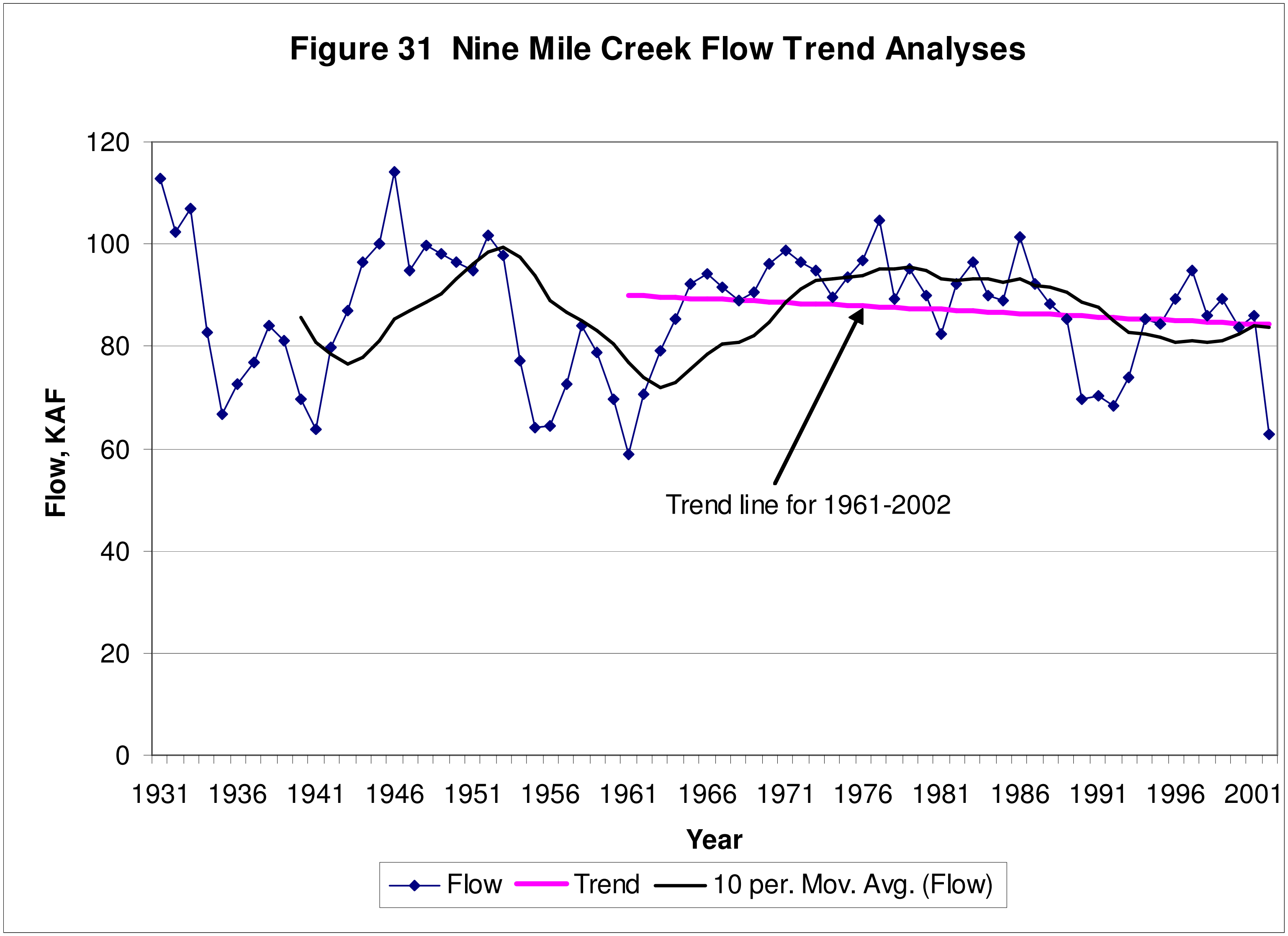


Figure 31 Nine Mile Creek Flow Trend Analyses
120
100
80
60
40
20
0
Flow, KAF
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Trend line for 1961-2002
Flow
Trend
10 per. Mov. Avg. (Flow)

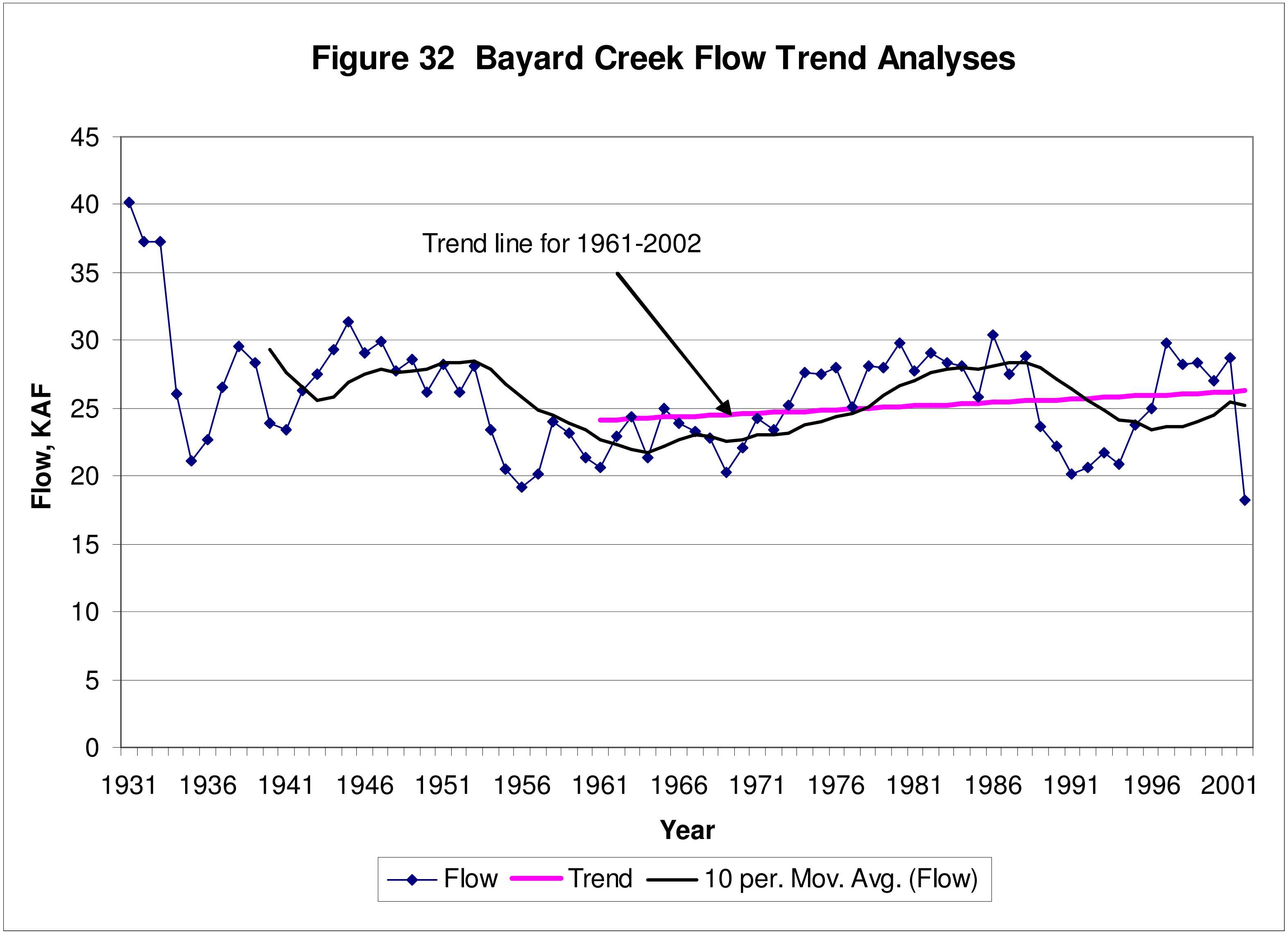


Figure 32 Bayard Creek Flow Trend Analyses
Trend line for 1961-2002
Flow, KAF
45
40
35
30
25
20
15
10
5
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

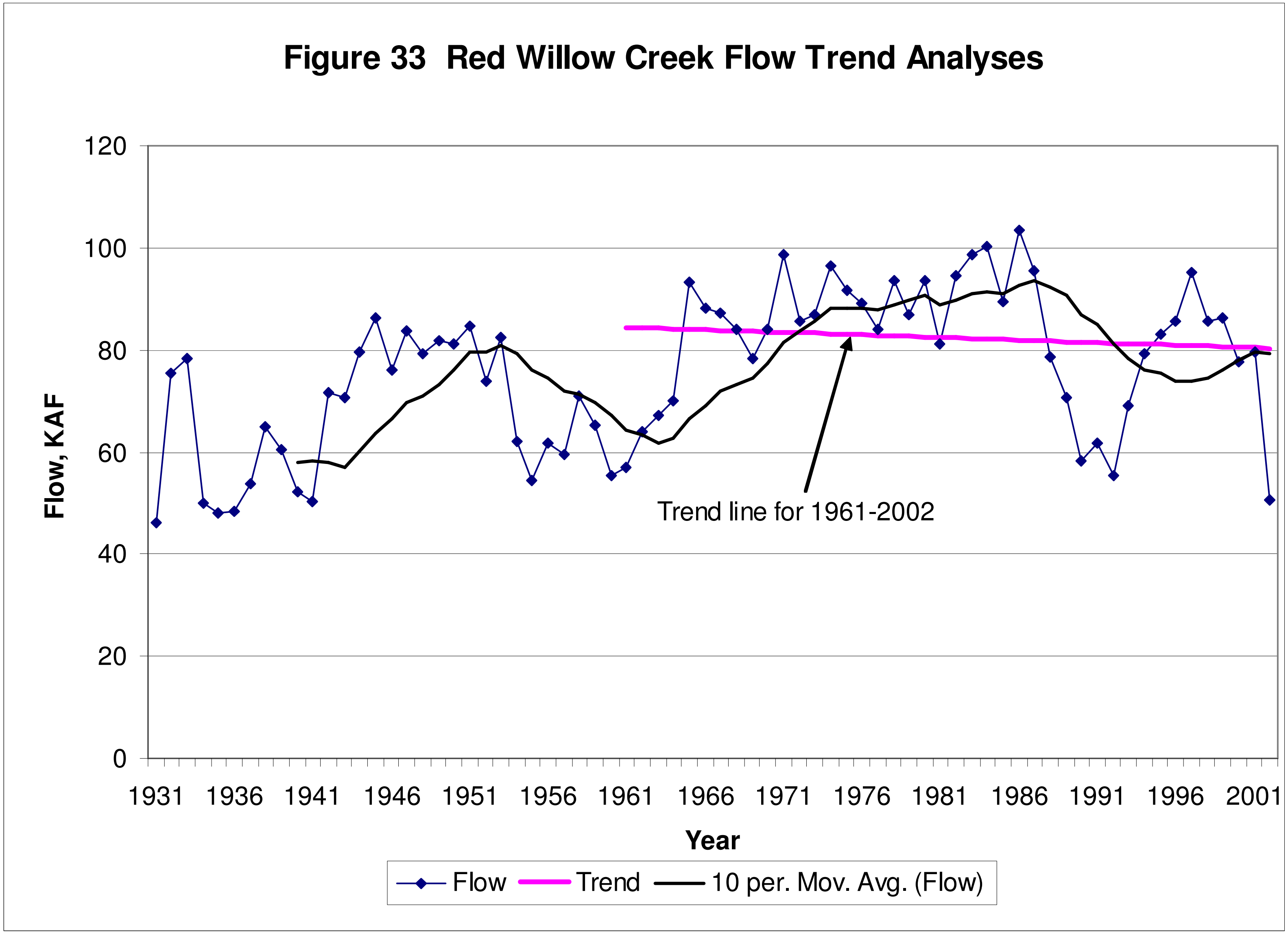


Figure 33 Red Willow Creek Flow Trend Analyses
120
100
80
60
40
20
0
Flow, KAF
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Trend line for 1961-2002
Flow
Trend
10 per. Mov. Avg. (Flow)

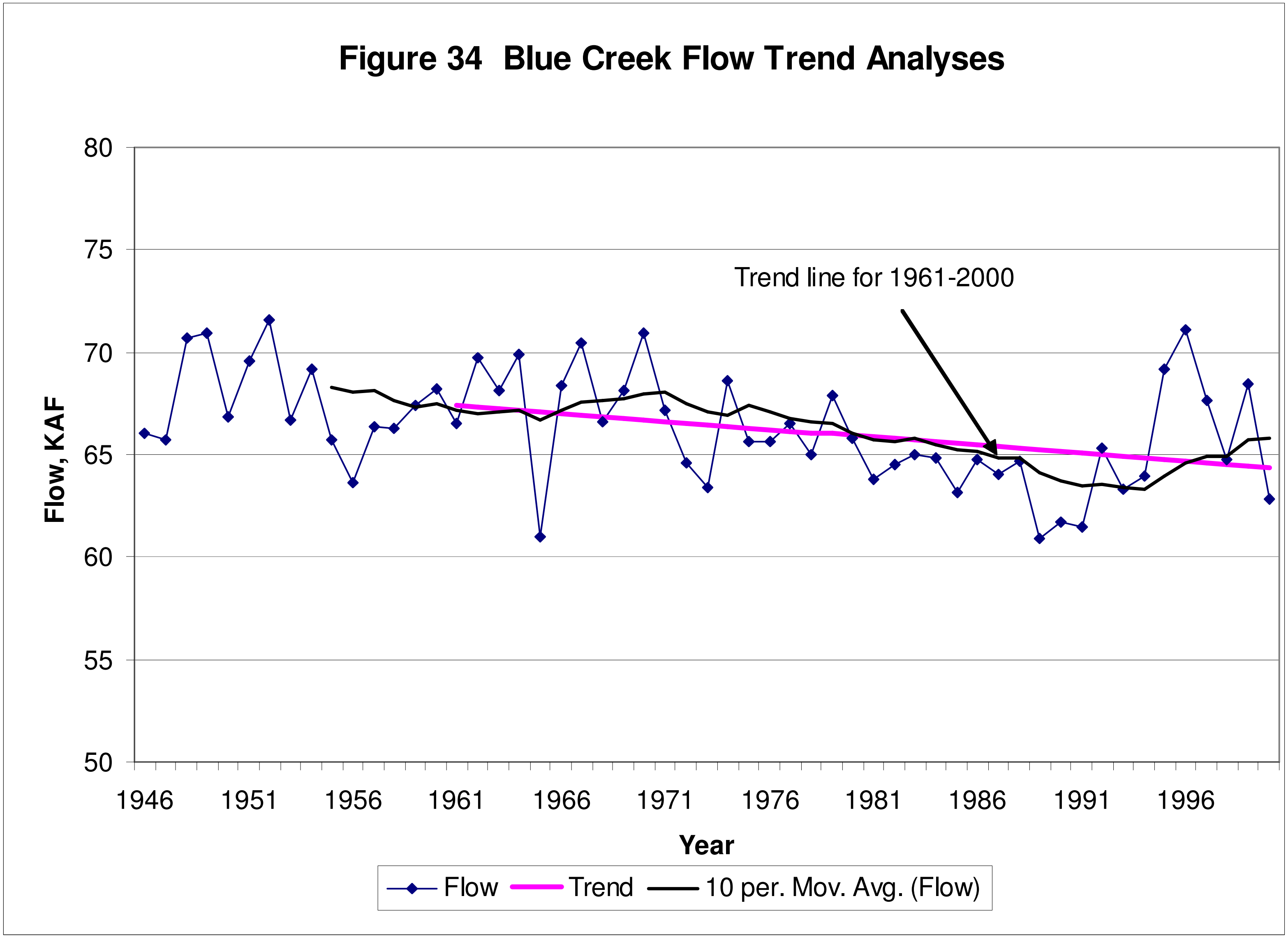


Figure 34 Blue Creek Flow Trend Analyses
80
75
70
65
60
55
50
Flow, KAF
Trend line for 1961-2000
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

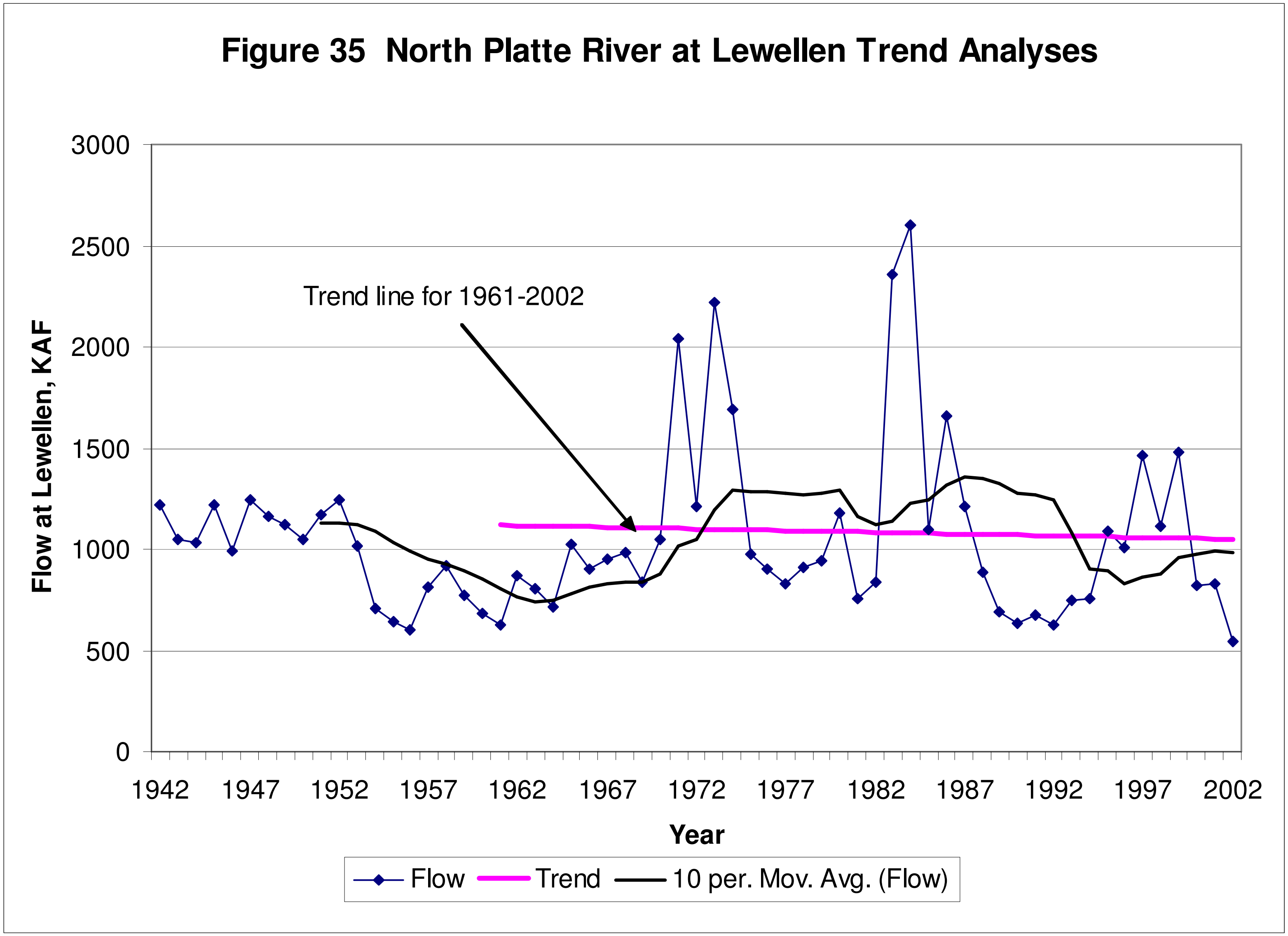


Figure 35 North Platte River at Lewellen Trend Analyses
Trend line for 1961-2002
Flow at Lewellen, KAF
0
500
1000
1500
2000
2500
3000
1942
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

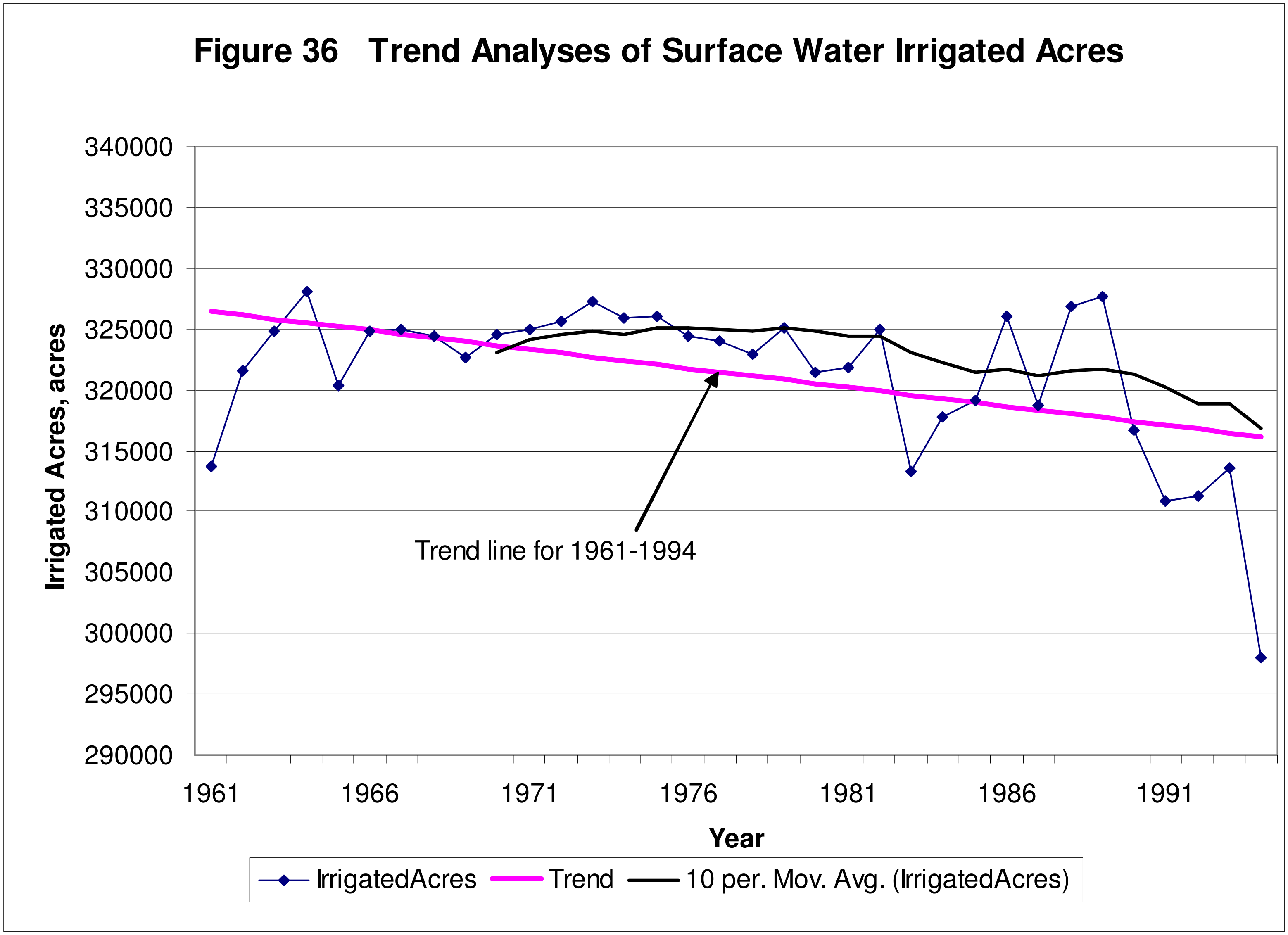
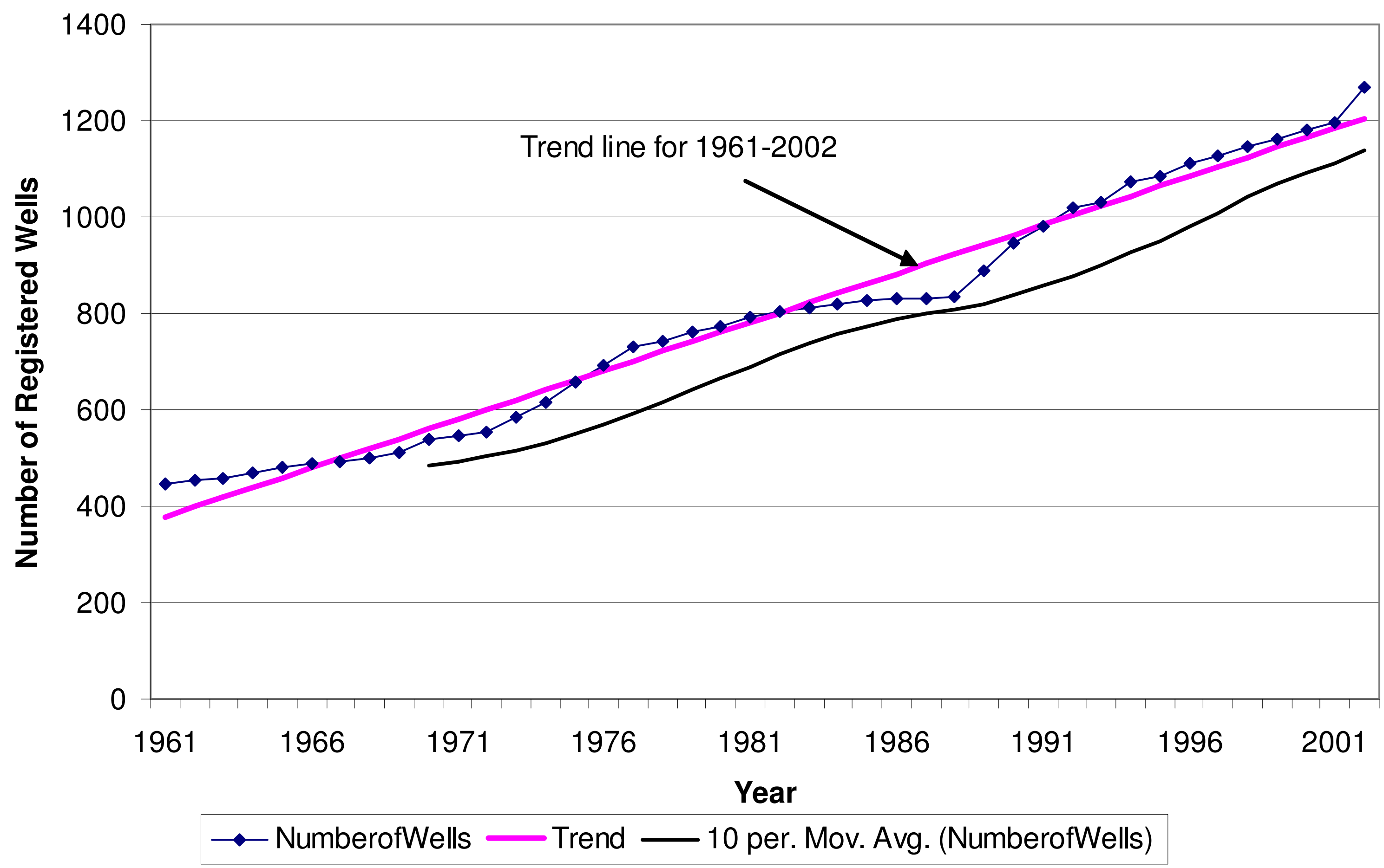


Figure 36   Trend Analyses of Surface Water Irrigated Acres
340000
335000
330000
325000
320000
315000
310000
305000
300000
295000
290000
Irrigated Acres, acres
1961
1966
1971
1976
1981
1986
1991
Year
Trend line for 1961-1994
IrrigatedAcres
Trend
10 per. Mov. Avg. (IrrigatedAcres)

Figure 37 Trend Analyses of Number of Registered Wells



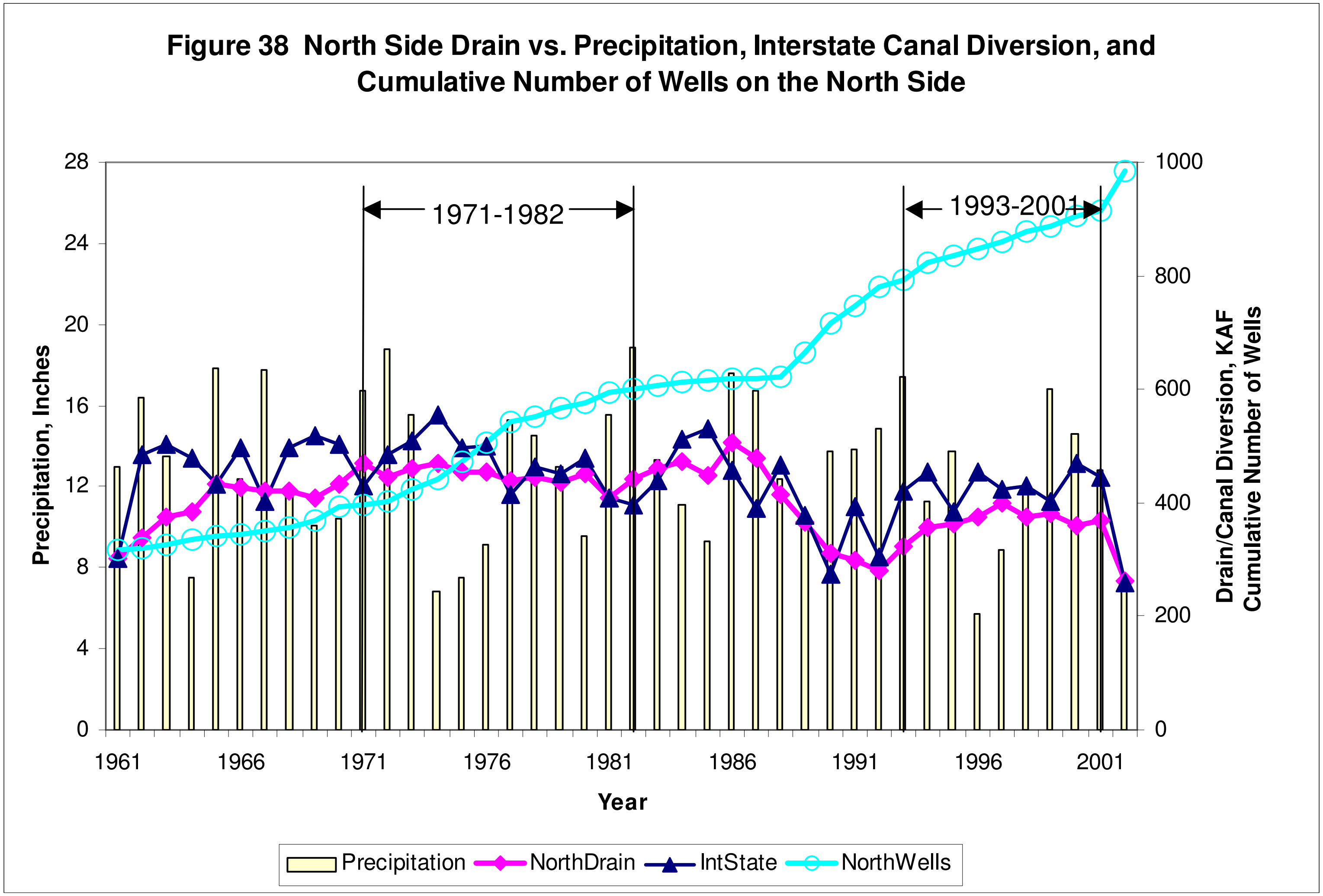


Figure 38 North Side Drain vs. Precipitation, Interstate Canal Diversion, and Cumulative Number of Wells on the North Side
1971-1982
1993-2001
Precipitation, Inches
Drain/Canal Diversion, KAF
Cumulative Number of Wells
Year
0
4
8
12
16
20
24
28
0
200
400
600
800
1000
1961
1966
1971
1976
1981
1986
1991
1996
2001
Precipitation
NorthDrain
IntState
NorthWells